PLUME RESPONSE PLAN (PRP)

PREPARED FOR THE PLUME MANAGEMENT PROCESS ACTION TEAM

JUNE 1994

MASSACHUSETTS MILITARY RESERVATION

EXECUTIVE SUMMARY

The fragile environment of Cape Cod, including the Sagamore Lens of its sole-source aquifer, is being threatened by plumes of contaminated groundwater emanating from the Massachusetts Military Reservation (MMR), also known as Otis Air Force Base. For the last ten years a remediation effort, under the provisions of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), has been exploring and studying these fast-moving plumes, but to date only one plume's advance has been checked. This report presents a proposal to redirect and accelerate the effort toward early and simultaneous containment of all plumes.

The Installation Restoration Program (IRP) addresses the massive problem of remediating over 70 contamination sites on the Base and ten plumes of contaminated groundwater emanating from it. Efforts over the past decade have succeeded in characterizing the areas of contamination and defining the content and location of all but one of the plumes. Only one plume has been contained; the rest are advancing into the developing residential areas served by the aquifer at the rate of one to two feet per day. There is agreement among groundwater professionals that current technology is not, in any practical way, capable of restoring the aquifer to pristine conditions. However, the water in the aquifer can be restored to meet maximum contaminant levels (MCLs) and drinking water quality.

In the past ten years, more than 53 billion gallons of aquifer have been lost, and with every passing day approximately 8 million more gallons become contaminated. This report concludes that a program of immediate containment for all plumes, on a definite, accelerated schedule, is essential because:

- The water supply of Upper Cape towns and the MMR is seriously threatened. Public and private wells have been and are being shut down, increasing the burden on remaining water supplies, which, in turn, have their areas of potential expansion diminished.

- Contaminants are presently flowing into the region's ponds and beneath residential areas presenting recognized health threats to humans and animals (Section 2.0) and potentially damaging the economic well-being of the area (Section 3.0). The Agency for Toxic Substance and Disease Registry has declared the contamination from the MMR to be a public health hazard, adding to the existing fears in the community about elevated incidence of certain forms of cancer (as described in Section 2.0). Because the plumes have advanced

beyond Base boundaries, pathways to humans and animals have rapidly increased in number.

- Limiting the spread of contaminated groundwater is required by the words of the CERCLA regulations and the intent of the law.

- The community, as demonstrated in newspaper editorials, letters to the editor, and comments to selectmen at public meetings, will not accept the low rate of progress inherent to the normal CERCLA process.

The community, represented by local elected officials and activist groups, and with the participation of the Massachusetts Department of Environmental Protection (MDEP), U. S. Environmental Protection Agency (USEPA) and National Guard Bureau (NGB), has fully considered the alternatives and prepared a plan for the design and installation of containment systems for the seven delineated plumes which still flow unchecked from the Base. Implementation of this plan will stop the advance of seven plumes by using extraction wells and processing of the contaminated water through granular activated carbon. The flow of contaminants into Johns and Ashumet Ponds will be interdicted. At the conclusion of this four-to-five-year effort, all but one of the known plumes will be contained by a cost-effective, integrated containment and treatment system.

The conceptual model for the containment of the plumes is described in this report. The recommended approach is the installation of a series of well fences pumping contaminated groundwater to a central location for treatment prior to reinjection back at the site of the leading edges of the various plumes. Alternatives to an "all at once approach," including individual treatment units, are also considered as part of this report. Detailed costs are provided for the conceptual model and are based on models derived from the RACER cost modeling program. Additional costs where needed are derived from manufacturers' information. Total cost of the recommended conceptual containment system is estimated at $100 million in 1994 dollars.

Under normal conditions, the time expected for the construction and start-up of this project is estimated at 72 months. However, with the assistance of Federal, State and local regulatory agencies, continued pressure from nearby communities, and fiscal support of the project, the time required for start-up is expected to be shortened to 42 to 48 months.

It is proposed that this program be managed, in accordance with CERCLA, as a single, urgent, interim action (see Section 5.0). The report provides recommendations for continued public participation in the definition and management of the accelerated program (see Section 6.0).

The benefits of this accelerated program include:

- **Large reductions in future health risk** to humans and animals, through the prevention of pathway proliferation.

- **Preservation of the sole-source aquifer**.

- **Avoidance of the enormous increase in the cost of remediation** otherwise associated with the continued advance of the plumes. Additional cost savings will be accrued due to the integrated approach in design, documentation, procurement, installation and operation.

- **Moderation of the negative economic impact** that Base contamination sites and plume proximity may have had upon the community.

Finally, the early containment of the plumes provides time in which to further the development of new and, hopefully, passive means for aquifer remediation at reduced cost.

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LIST OF ACRONYMS

ANG	Air National Guard
ANGRC	Air National Guard Readiness Center
ARNG	Army National Guard
ATSDR	Agency for Toxic Substance and Disease Registry
AVGAS	Aviation gasoline
BBM	Buzzards Bay Moraine
BLS	Below Land Surface
BOMARC	Boeing Michigan Aeronautical Research Center
BTEX	Benzene, toluene, ethylbenzene, and xylenes
BU	Boston University
CCl_4	Carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CGN	Camp Good News
CTU	Central treatment unit
CS	Chemical spill
DCE	Dichloroethylene
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DPDO	Defense Property Disposal Office
EDB	Ethylene dibromide
FFA	Federal Facility Agreement
FS	Feasibility Study
FS	Fuel spill
FTA	Fire Training Area
ft/d	Feet per day
ft/ft	Feet per foot
GAC	Granular activated carbon
gpm	Gallons per minute
GRS	Groundwater Remediation Strategy
HAZWRAP	Hazardous Waste Remedial Actions Program
ID	Inside diameter
IRP	Installation Restoration Program
ITU	Individual treatment unit
km	Kilometer
lbs	Pounds
LF	Landfill
MCL	Maximum Contaminant Level
MDEP	Massachusetts Department of Environmental Protection
MDPH	Massachusetts Department of Public Health
MMR	Massachusetts Military Reservation
MPP	Mashpee Pitted Plain
MSL	Mean sea level
NCP	National Contingency Plan
NDIL	Non-Destructive Inspection Laboratory

LIST OF ACRONYMS (Concluded)

NGB	National Guard Bureau
NPL	National Priorities List
O&M	Operation and Maintenance
OpTech	Operational Technologies Corporation
PAT	Process Action Team
PCE	Perchloroethylene
PFSA	Petroleum Fuels Storage Area
ppb	Parts per billion
ppm	Parts per million
PRP	Plume Response Plan
psi	Pounds per square inch
PVC	Polyvinyl chloride
RA	Remedial Action
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
SD	Storm drain
SM	Sandwich Moraine
SMB	Senior Management Board
STP	Sewage treatment plant
SVOC	Semivolatile Organic Compound
TAL	Target Analyte Metals
TCA	1,1,1-trichloroethane
TCE	Trichloroethylene
TCL	Target Compound List
TEAC	Technical Environmental Affairs Committee
TIC	Tentatively identified compounds
μg/L	Micrograms per liter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
UTES	Unit Training Equipment Support
VOC	Volatile Organic Compound

SECTION 1.0 PROBLEM DEFINITION

Past releases of oil and hazardous materials at the MMR have resulted in extensive groundwater contamination. Documented sources of contamination include former motor pools, landfills, fire training areas, and drainage structures such as dry wells. Nine major plumes of groundwater contamination (Table 1.1) were found to be migrating from these source areas and have been defined through extensive groundwater investigations. Recent field investigations have indicated the presence of a tenth plume emanating from a Fuel Dump Valve Test Site (FS-1). Further investigations are planned to determine the severity of the contamination at that site. The Landfill-1 (LF-1) Plume, the Ashumet Valley Plume, the Storm Drain-5 (SD-5) Plume, the Petrol Fuels Storage Area (PFSA) Plume, the Eastern Briarwood Plume, and the Fuel Spill-12 (FS-12) Plume have all migrated off the MMR facility. The Chemical Spill-10 (CS-10) Plume and the Western Aquafarm Plume are approaching the facility boundary. One plume, the Chemical Spill-4 (CS-4) Plume, has been contained with pumping wells to manage the migration of contaminants and prevent further pollution of downgradient areas and an operating municipal well in the Town of Falmouth. The PFSA plume has been found to be undergoing natural biodegradation and is not included for action in this plan.

Table 1.1
Plume Information

Plume Identification	Source
LF-1	Main Base Landfill
CS-10	Boeing Michigan Aerospace Research Center (BOMARC) Facility
PFSA	Petrol Fuel Storage Area (PFSA)
SD-5 (NDIL)	Storm Drain-5 (Non-Destructive Inspection Laboratory (NDIL))
Eastern Briarwood	MMR Industrial Area
Western Aquafarm	Underground Storage Tanks (USTs), Fuel Transfer System
CS-4	Motor Pool & Defense Property Disposal Office (DPDO)
FS-12 (Sandwich)	Cape Cod Canal Fuel Transfer Line
FS-1	Fuel Dump Valve Test Site
Ashumet Valley (FTA-1)	Sewage Treatment Plant and Fire Training Area 1 (FTA-1)

The seven plumes that continue to migrate unchecked pose a continued threat to public health, the environment, and the quality of life of residents of the Towns of Bourne, Falmouth, Mashpee, and Sandwich on western (upper) Cape Cod.

Groundwater contaminants within the seven plumes include chlorinated solvents such as trichloroethylene (TCE) and perchloroethylene (PCE), and fuel-related compounds such as benzene. These pollutants, many of which are known carcinogens, are found in concentrations well in excess of drinking water standards and pose a significant risk to public health. The presence of multiple contaminants within individual plumes increases the risk associated with use of contaminated water for domestic purposes. A list of major chemical constituents in each plume and associated drinking water standards is presented in Table 1.2.

Table 1.2
Major Chemical Constituents of MMR Groundwater Plumes

Plume Identification	Chemical Contaminants*
LF-1	TCE, PCE, CCl_4, Vinyl Chloride, Metals**
CS-10	TCE, PCE, 1,1-DCE
LF-1	Benzene, Ethylbenzene
SD-5 (NDIL)	TCE, 1,1-DCE, PCE and Methylene Chloride
Eastern Briarwood	PCE, Benzene
Western Aquafarm	BTEX
CS-4	TCE, PCE, DCE
FS-12 (Sandwich)	Benzene, EDB
FS-1	Undetermined at this time
Ashumet Valley (FTA-1)	1,2-DCE, PCE, TCE

*Maximum contaminant levels – Parts per billion.
TCE – 5.
PCE – 5.
CCl_4 – 5.
Vinyl Chloride – 2.
1,1-DCE – 7.
1,2-DCE – 70.
Benzene – 5.
Ethylbenzene – 700.
EDB – 0.02.
**Arsenic – 50.
**Chromium – 100.
**Lead – 15.
TCE – Trichloroethylene.
PCE – Perchloroethylene.
CCl_4 – Carbon Tetrachloride.
DCE – Dichloroethylene.
EDB – Ethylene Dibromide.
BTEX – Benzene, Toluene, Ethylbenzene, Xylenes.

Through designation as a Sole-Source Aquifer, the United States government has recognized the essential nature of Cape Cod's groundwater supply. This is the only water available to the residents of the Cape and is considered to be of excellent natural quality. Groundwater withdrawn from the Cape Cod aquifer provides 100 percent of the water supply in the region through private wells, municipal water supply wells, and one groundwater-fed surface pond. The existing plumes currently affect a significant area of the aquifer (Figure 1.1). The area will increase as the plumes continue to migrate and spread at a rate of several feet per day as is indicated in Figure 1.2. These projected plume locations are based on estimates of groundwater

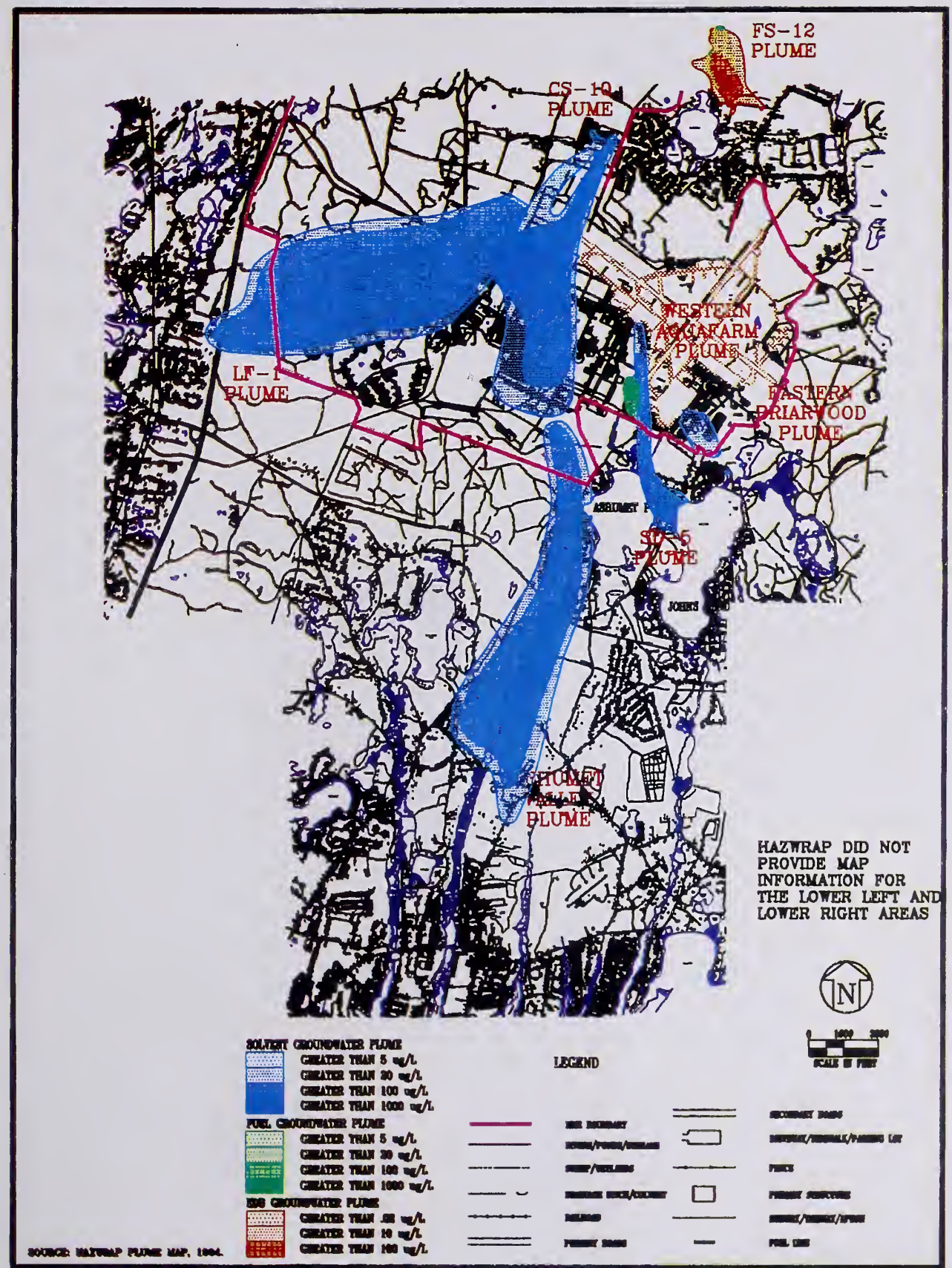

FIGURE 1.1

PLUME AREA MAP

MASSACHUSETTS MILITARY RESERVATION

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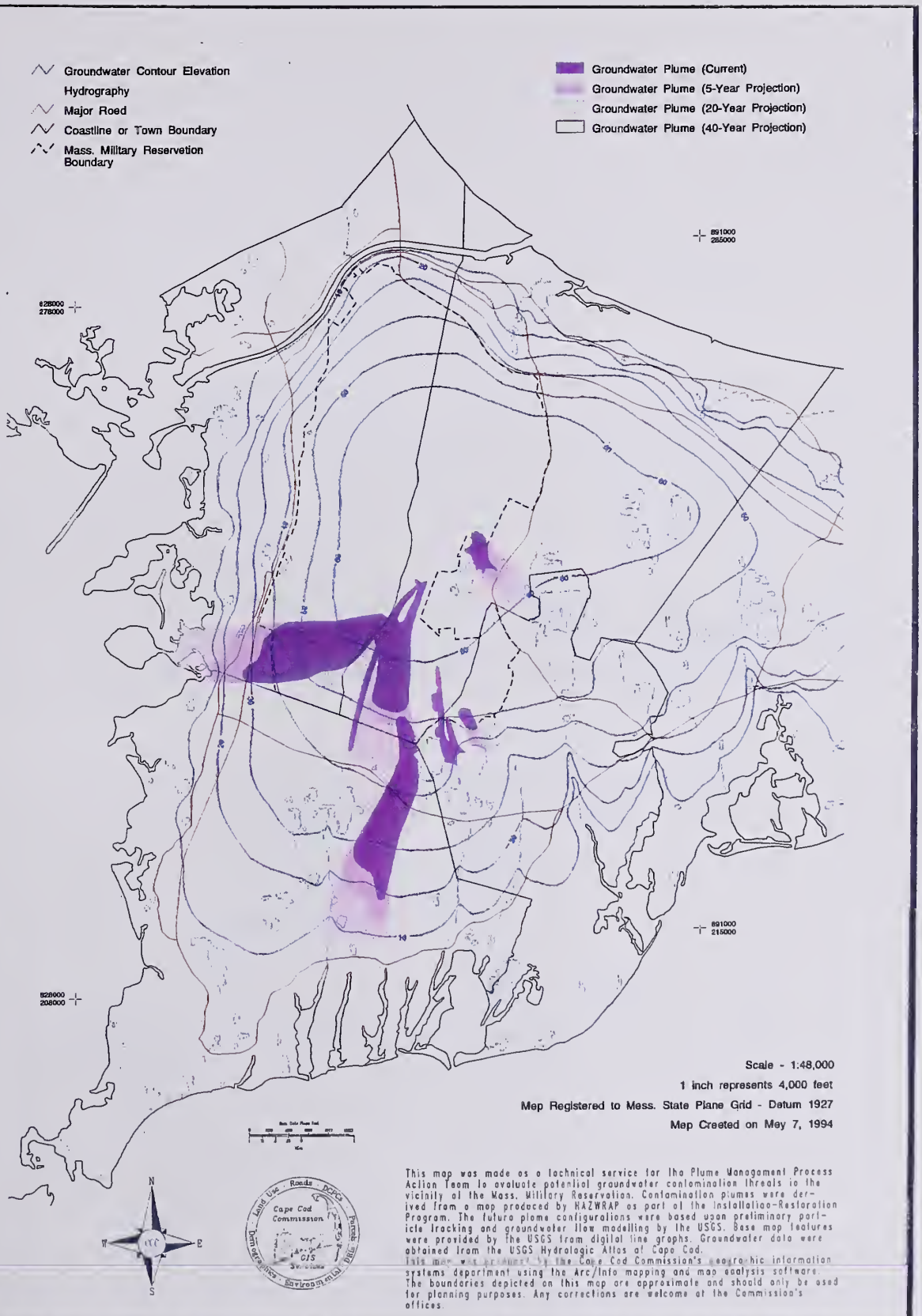
Groundwater Contour Elevation
Hydrography
Major Road
Coastline or Town Boundary
Mass. Military Reservation Boundary
Groundwater Plume (Current)
Groundwater Plume (5-Year Projection)
Groundwater Plume (20-Year Projection)
Groundwater Plume (40-Year Projection)
891000
285000
828000
278000
891000
215000
828000
208000
Scale - 1:48,000
1 inch represents 4,000 feet
Map Registered to Mass. State Plane Grid - Datum 1927
Map Created on May 7, 1994
This map was made as a technical service for the Plume Management Process Action Team to evaluate potential groundwater contamination threats in the vicinity of the Mass. Military Reservation. Contamination plumes were derived from a map produced by NAZWRAP as part of the installation-Restoration Program. The future plume configurations were based upon preliminary particle tracking and groundwater flow modelling by the USGS. Base map features were provided by the USGS from digital line graphs. Groundwater data were obtained from the USGS Hydrologic Atlas of Cape Cod.
This map was produced by the Cape Cod Commission's geographic information systems department using the Arc/Info mapping and map analysis software. The boundaries depicted on this map are approximate and should only be used for planning purposes. Any corrections are welcome at the Commission's offices.
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S
E
W
Cape Cod Commission
GIS

FIGURE 1.2

PROJECTED PLUME PATHS
MASSACHUSETS MILITARY RESERVATION

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JUNE 1994

velocities from IRP investigations of individual plumes and an analysis of regional groundwater flow with the U. S. Geological Survey's (USGS) computer model. An estimate of the rate of plume migration, obtained from the computer model, indicates that up to 211 acres of additional land surface will be underlain by plumes each year. This presents additional lost water resources of over 2.9 billion gallons per year. Continued plume migration over the next 20 years would result in over 32 billion gallons of additional polluted water. It is well known that, once polluted, groundwater quality is very difficult to restore.

Several of the migrating plumes have already contaminated private and municipal wells. In 1979, the Town of Falmouth's Ashumet Well, a one-million-gallon-per-day supply, was closed because of contamination from the Ashumet Valley Plume. Private wells in the Ashumet Valley and the Briarwood area of Mashpee had to be replaced by public supplies because they were in the paths of the SD-5 and Eastern Briarwood Plumes. Towns threatened by plume migration are already experiencing water shortages. For example, the Town of Falmouth has had to implement restrictions on water use during the past six summers. Significant water shortages have been predicted for all of western Cape Cod. Figures 1.3 and 1.4 illustrate water supply shortfalls anticipated without consideration of additional areas that may be lost due to migrating plumes from the MMR.

The problem of lost water supplies is likely to worsen if the advancing plumes are not contained. Concentrations of contaminants exceeding drinking water standards and posing a significant carcinogenic risk are expected to reach additional water supply wells as the contaminant plumes continue to migrate and spread at a rate of more than one foot per day. The Well Protection Zones mapped for municipal supply wells in the four western Cape Cod towns (Figure 1.5) illustrate the future effect of plume migration on public wells. Comparison of these zones with the predicted paths of the plumes clearly demonstrates that the MMR plumes will contaminate these wells unless timely actions are taken. Numerous irrigation wells with capacities in excess of 100,000 gallons per day and many private wells for domestic and commercial supply are also in the paths of the migrating plumes. Replacement of these supplies would be difficult because the area available for future water supply development has been severely restricted by the present and projected locations of the plumes.

Critical aquatic environments are also in the path of continued plume migration. The natural environment on Cape Cod includes recreational ponds, groundwater-fed trout streams and herring runs, and coastal embayments providing habitat for shellfish and juvenile finfish. Plume contaminants may cause significant stress on aquatic ecosystems. These ecosystems have an intrinsic value, and ecological resources are also essential to the quality of life on Cape Cod.

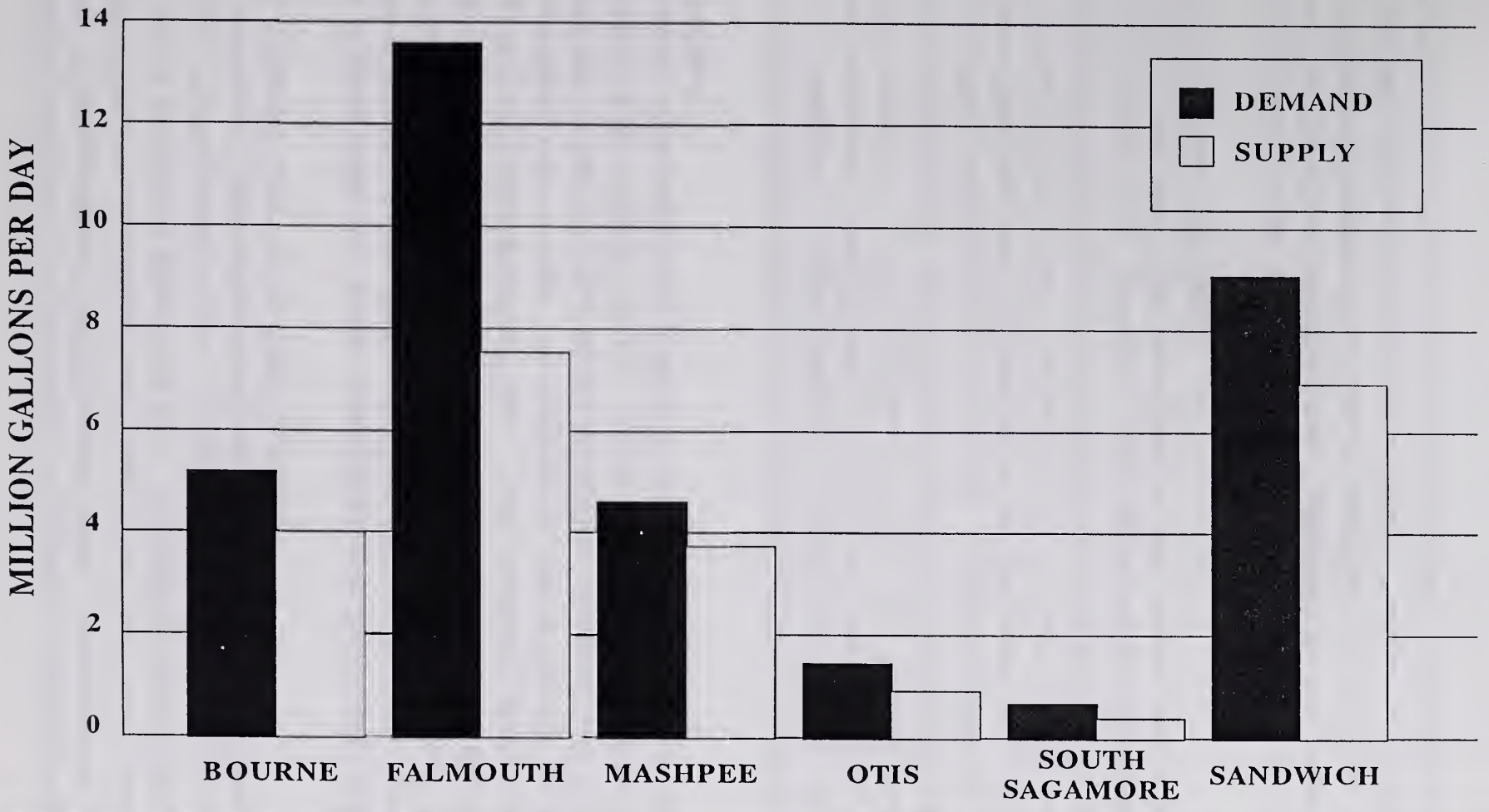

FIGURE 1.3

LOCAL SUPPLY vs DEMAND IN THE YEAR 2020
MASSACHUSETTS MILITARY RESERVATION

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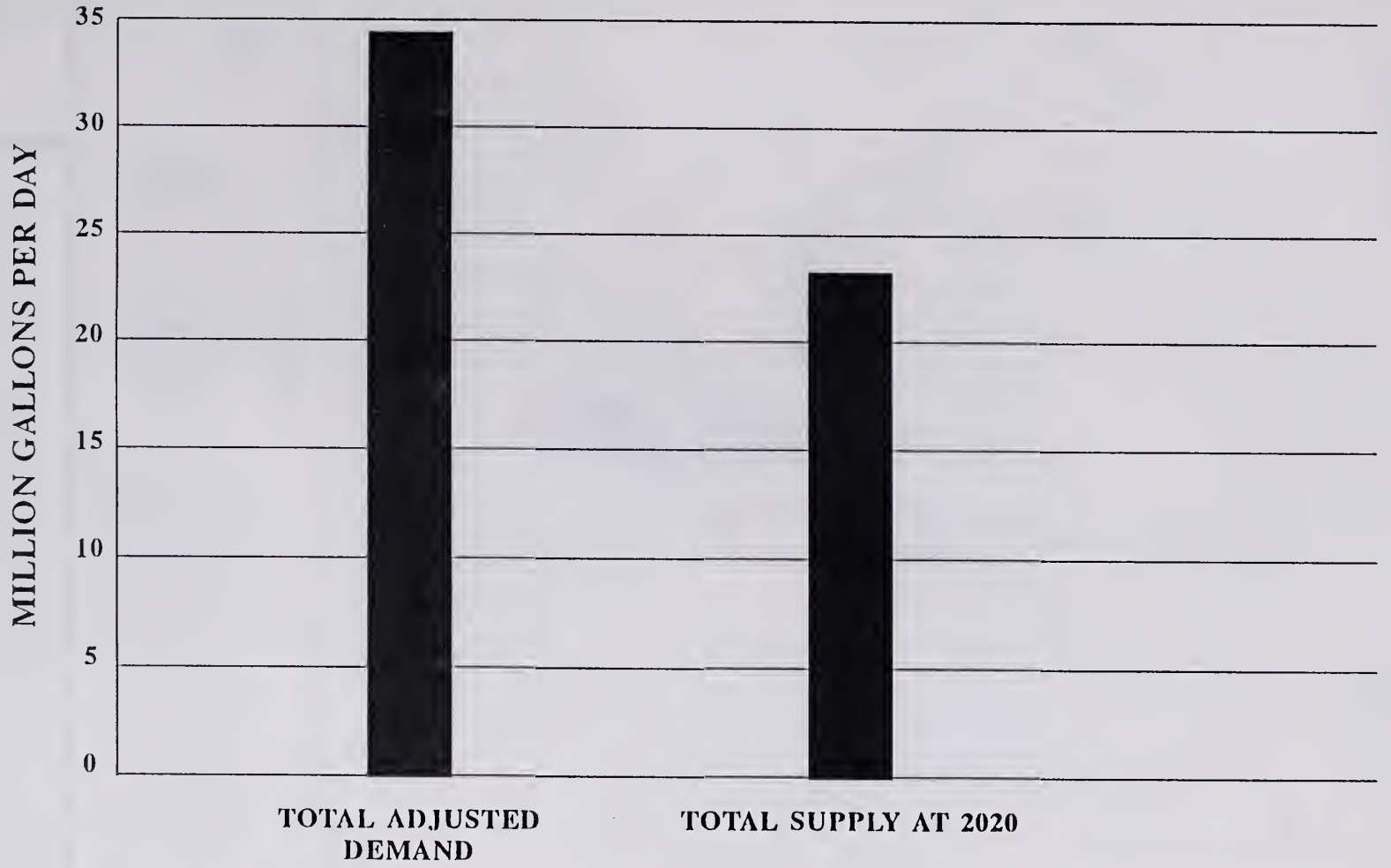

FIGURE 1.4

REGIONAL SUPPLY vs DEMAND IN THE YEAR 2020
MASSACHUSETTS MILITARY RESERVATION

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JUNE 1994

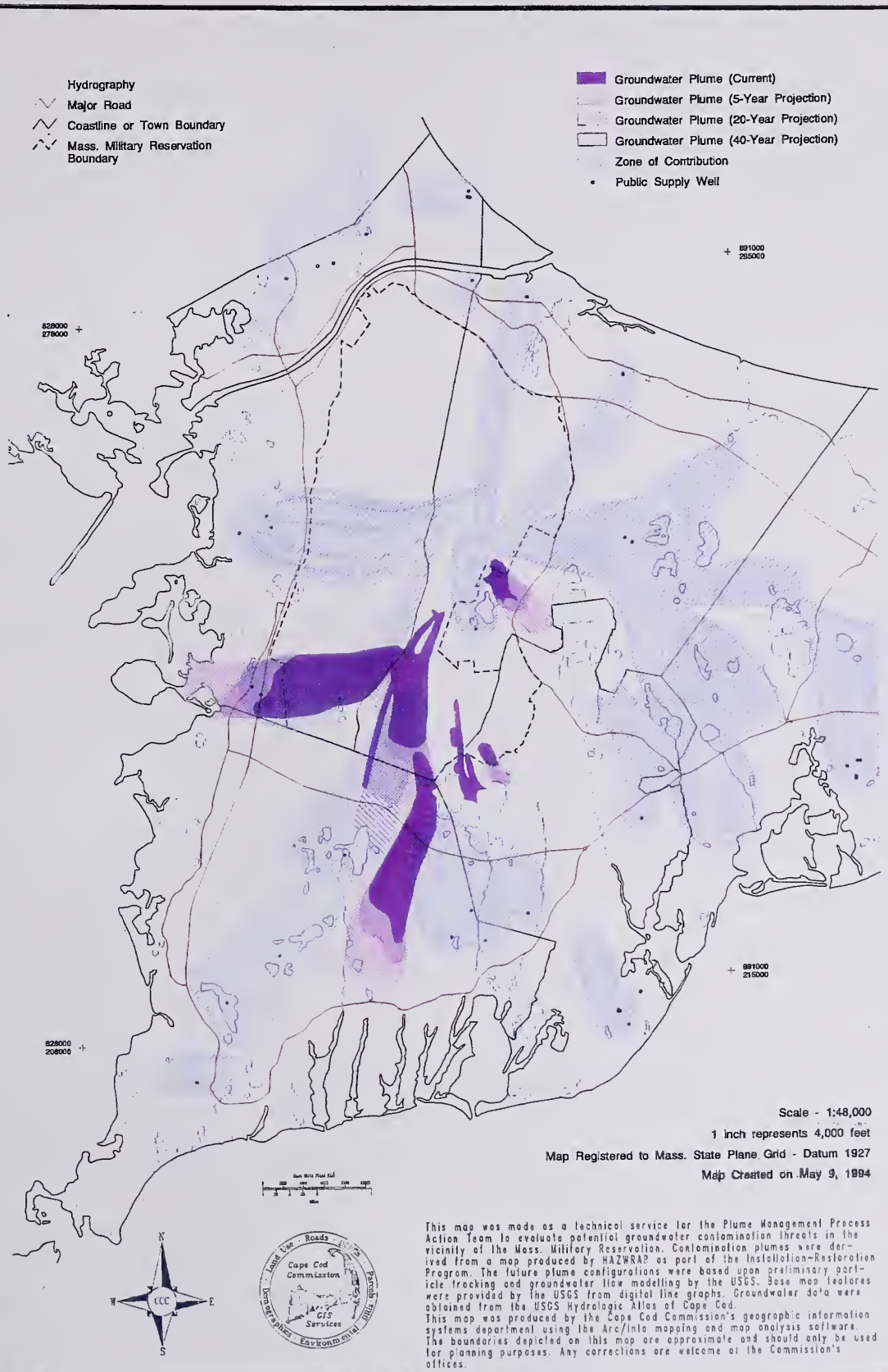

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FIGURE 1.5

PROJECTED PLUME PATHS
MASSACHUSETS MILITARY RESERVATION

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Landfill-1 (LF-1) Plume

The LF-1 Plume (Figure 1.1), originating at the Main Base Landfill, extends more than 16,500 feet downgradient with a width of 6,000 feet and a current volume of 22 billion gallons. Contaminants include volatile organic compounds with maximum concentrations of 64 parts per billion (ppb) TCE, 65 ppb PCE, 60 ppb carbon tetrachloride (CCl_4), and 8 ppb vinyl chloride. Elevated metals were also noted in the plume.

Continued migration of the LF-1 plume would result in the contamination of downgradient receptors including residential private wells, municipal supply wells at Bourne Pumping Stations 2 and 5, groundwater resources, and contamination of productive coastal marine environments.

Ashumet Valley Plume

The source of the Ashumet Valley Plume (Figure 1.1) includes FTA-1, and CS-16 and CS-17. CS-16 and CS-17 are associated with the sand filter beds and sludge drying beds at the Base wastewater treatment plant. Past disposal of solvents and fuel sludges at these locations has contributed to groundwater contamination found in the Ashumet Valley Plume. The wastewater treatment plant is currently being replaced with a new facility and discharge locations.

The Ashumet Valley Plume extends 18,750 feet downgradient and is 4,000 feet wide. More than 13 billion gallons of groundwater have already been contaminated. Volatile organic compounds exceeding maximum contaminant levels include 1,200 ppb 1,2-dichloroethylene (DCE), 982 ppb PCE, and 95 ppb TCE. Numerous other organic and inorganic contaminants have been identified in the plume.

Downgradient receptors contaminated and endangered by the Ashumet Valley Plume include a municipal supply well, private water supply wells, clean groundwater resources, freshwater recreational ponds, and coastal embayments with productive shellfish beds.

Fuel Spill-12 (FS-12) Plume

FS-12 (Figure 1.1) is associated with a leak in a former fuel transfer pipeline. The exact volume of the leak is unknown; however, based on assessed conditions, it has been estimated as high as 70,000 gallons.

The area of groundwater contamination from FS-12 extends 5,000 feet downgradient from the source area forming a 2,500-foot-wide plume contaminating 1.5 billion gallons. Contaminants of concern include fuel-related compounds such as benzene, found at 1,600 ppb, and 597 ppb of ethylene dibromide (EDB), a probable human carcinogen.

The FS-12 plume is currently located beneath a children's summer camp and is migrating toward residential areas with private water supply wells, clean groundwater resources, and recreational ponds. Municipal wells are also threatened by the plume.

Chemical Spill-10 (CS-10) Plume

A former Boeing Michigan Aeronautical Research Center (BOMARC) missile facility and tracked vehicle maintenance area comprises the source of the CS-10 Plume. Contaminants were disposed in drainage structures at the facility, resulting in groundwater contamination currently defined as extending 12,500 feet downgradient and over 3,600 feet wide. More than 13 billion gallons of groundwater have been degraded. Contamination includes up to 3200 ppb TCE, 500 ppb PCE, and 58 ppb 1,2-DCE.

Continued migration of the CS-10 Plume may contaminate recreational ponds, private wells, groundwater resources, Falmouth water supply wells at Coonamesett Pond, Well 4D, the Mares Pond Well, and proposed wells 1D and 1E. The Long Pond water supply may also be contaminated.

Petrol Fuel Storage Area (PFSA) Plume

The PFSA at MMR has been used to handle and store bulk fuel for flight line operations. Significant spills of petroleum have occurred in the area, resulting in groundwater contamination. A plume of fuel-related contaminants extends 3,250 feet downgradient with a width of 700 feet, contaminating 97 million gallons of groundwater. Up to 100 ppb of fuel-related compounds have been detected with no exceedances of maximum contaminant levels (MCLs). A recreational pond is located downgradient of the plume.

Storm Drain-5 (SD-5) Plume

The SD-5 Plume originates in the vicinity of the former Non-Destructive Inspection Laboratory on MMR where solvents were disposed in dry wells. The plume extends 10,000 feet downgradient and is up to 1,750 feet wide. Contaminants of concern in the SD-5 Plume include

up to 59 ppb TCE, 110 ppb 1,2-DCE, and other volatile organic compounds (VOCs). An estimated 2 billion gallons of groundwater have been contaminated.

The SD-5 plume has contaminated private wells and is posing a threat of further contamination of the groundwater resource. The plume is currently discharging to a recreational pond in a residential community.

Western Aquafarm Plume

This plume originates from a former underground bulk fuel storage facility near the flight line at MMR. The plume is 800 feet wide and extends 2,000 feet downgradient from the source area. Over 65 million gallons of groundwater are contaminated with fuel-related compounds. Ethylbenzene has been found above its MCL at up to 910 ppb in the plume.

The Western Aquafarm Plume is threatening additional groundwater resources and a recreational pond downgradient.

Eastern Briarwood Plume

The Eastern Briarwood Plume originates at several diffuse sources in a highly industrialized area of MMR south of the flight line. Chlorinated solvents, including PCE at 14 ppb, and fuel-related compounds such as benzene at 6 ppb, have been identified in a plume 1,200 feet wide extending 2,500 feet downgradient. Over 160 million gallons of groundwater have been contaminated by the plume.

A recreational pond, trout stream, and cranberry bog system are located downgradient and threatened by continued migration of the plume.

FS-1 Plume

The FS-1 Plume, currently under investigation, originates at a former fuel dump valve test site where aircraft practiced dumping fuel to prepare for crash landings. An estimated 400,000 to one million gallons of aviation gasoline were released at the source area. Additional investigations are ongoing to determine the extent of contamination, and remedial actions may be necessary in the future but are not included in this plan.

Carcinogenic and non-carcinogenic risks to public health calculated for the CS-10, LF-1, FS-12, Ashumet Valley, Western Aquafarm, SD-5, and Eastern Briarwood plumes were all found to exceed acceptable risk ranges as set forth in the National Contingency Plan, as well as regulatory limits when compared to State and Federal standards. In the Federal National Contingency Plan, cancer risks are compared to a risk range of 1.00E-04 to 1.00E-06. The Massachusetts Contingency Plan specifies a limit of 1.00E-05. State and Federal regulations specify a non-carcinogenic hazard index not to exceed 1. Quantified risks are presented in Table 1.3.

Table 1.3
Summary of Groundwater Risks for Seven Plumes at the Massachusetts Military Reservation

Plume	Carcinogenic Risk		Non-Carcinogenic Risk	
	Child	Adult	Child	Adult
CS-10	1.99E-02	1.29E-03	177	14.1
LF-1	2.40E-03	3.39E-03	297	93.2
FS-12	*	1.01E+00	*	30.1
Ashumet	*	3.00E-04	*	7
Western Aquafarm	*	6.00E-04	*	21
SD-5	*	7.00E-04	*	10
Eastern Briarwood	*	1.00E-04	*	19

*Child risk not calculated separately.

Summary

The continued migration of plumes at MMR poses an unacceptable threat to public health and the environment. As required by the National Contingency Plan (NCP), remedial actions are necessary to minimize contaminant migration, minimize negative impact on the Cape Cod Sole-Source Aquifer, reduce the time required for restoration of the aquifer, and reduce risks to public health and the environment.

These objectives can be achieved through the use of interim measures. By taking the actions presented in this plan, the Department of Defense (DoD) can make significant progress toward cleanup, compliance with environmental laws, and prevention of pollution of downgradient resources.

SECTION 2.0 UNIQUE FEATURES OF THE UPPER CAPE SUPPORTING RAPID, COMPREHENSIVE REMEDIATION

2.1 INTRODUCTION

The Upper Cape possesses several unique factors making it highly desirable to residents and tourists alike: healthy air and water; the relatively mild year-round climate; ready access to recreational activities including salt and fresh water swimming, boating and fishing; and characteristic dunes and marshlands. The Upper Cape is within an hour's drive of the major urban centers of Boston and Providence and is a terminal point for ferry traffic to Martha's Vineyard and Nantucket. It is important to note that the southern shore of the Upper Cape is the northernmost occurrence of ocean considered by most people sufficiently warm for summer bathing. For this reason, the Upper Cape is visited by many tourists from Ontario and Quebec. It is not likely that the benefits of this area, if lost, could be fully recouped on other parts of the East Coast.

2.2 HISTORY

The area now known as the Massachusetts Military Reservation has been used for military purposes since 1911. Few military facilities in the United States have experienced the variety and intensity of activities as the MMR. Both the U. S. Army and the U. S. Air Force, including the Strategic Air Command, have utilized the MMR as a base of operations. The MMR is currently used by an Air National Guard 102nd Fighter Wing, the Massachusetts Army National Guard (including artillery, mortar and machine gun training), the U. S. Air Force's 6th Space Warning Squadron PAVE PAWS radar site, the 1st Battalion 25th Marines, and the U. S. Coast Guard (NGBPA, 1993). Many of these occupants have contributed to the environmental degradation of the Upper Cape.

The MMR is located over the highest point of the Sagamore Lens of the Cape's sole-source aquifer. At least nine plumes of contaminated groundwater radiate from the MMR toward and into densely populated neighboring residential communities. Approximately 112 billion gallons of the aquifer have so far been affected, with peak toxic concentrations about 50,000 times USEPA maximum contaminant levels. The high permeability of the Cape's sandy soil allows these plumes to advance rapidly toward private and municipal wells, ponds, and coastal areas. If downgradient migration of these plumes is not halted expeditiously, they will continue to contaminate existing future water supplies and enter coastal areas, potentially endangering productive shellfish beds and recreational areas. At a cost of approximately $80 million, the National Guard Bureau, after 10 years of study, has determined the location of contaminant

plumes with sufficient precision to permit development of a Conceptual Model of an effective, comprehensive containment system.

During the mid-1970s, a reduction in activities at the MMR was accompanied by the onset of rapid growth of the surrounding year-round population. MMR is now located in the midst of a community of 110,000 permanent residents which swells to 244,000 during the summer months. Thus, there is a dense ring of population, with the 22,000-acre MMR at its center and the ocean at most of its outer periphery. Rapid growth and limited availability of fresh water have led to projections of future shortages in water for drinking, bathing, and other household uses, even without the threat of advancing toxic plumes from the MMR.

The virtues of the Upper Cape have long been prized by members of the Wampanoag Tribe who live in close proximity to the MMR and gain vital resources from hunting, fishing and shellfishing. The traditional lifestyle of this indigenous minority could be severely threatened if groundwater pollution were not remedied.

2.3 ECONOMIC IMPACT

The recent decline of real estate prices in areas most proximate to the MMR has caused homes to be sold for less than the value of mortgages held on them. Since there is little manufacturing on the Upper Cape, local municipalities derive nearly all revenue from taxes on residences and tourist facilities. The rapid population increase of the past 15 years has forced town governments to assume large capital debts in order to construct new public schools and other community infrastructure. Further decline in property values, together with requests for abatements, could result in a precipitous collapse of the current debt structure.

2.4 HEALTH IMPACT

A critical factor in the emotional and economic well-being of the Upper Cape is the perception of a link between adverse health outcomes and toxic exposure. A recent Public Health Assessment by the Agency for Toxic Substance and Disease Registry (ATSDR, 1994:1) states:

> "After considering the completed human exposure pathways, community health concerns, and available health outcome data, ATSDR concludes that contamination originating from several areas on the MMR is a public health hazard."

Cancer rates have been elevated on the Upper Cape for many years. For example, according to data from the Massachusetts Department of Public Health (MDPH), female lung cancer mortality for the region was 38% above age-adjusted rates based upon State averages in 1979-1983, a statistically significant elevation. Among cancer incidence data on the Upper Cape for 1982-1990 (MDPH, 1993), the following age-adjusted elevations are most notable.

The Boston University (BU) Cancer Incidence Study (Aschengrau & Ozonoff, 1991) of selected cancers diagnosed in 1983-1986 contained two findings supporting the conclusion that policy makers employ the most conservative standards of risk assessment in remedying environmental insults at MMR.

- Table 2.1 shows a statistically significant odds ratio of 1.41 for all female cases in the study (including lung and colorectal whose odds ratios are 1.36 and 1.34, respectively) within 11 kilometer (km) of the MMR for residents exposed more than 20 years. When breast cancer cases were removed, the odds ratio becomes 1.60. ATSDR (1994:56,132) suggests that leukemia is the disease most responsible for this elevation. The odds ratio represents the incidence risk among a given case population to that in a randomly selected control group.

Table 2.1
Selected Upper Cape Cancer Incidence Elevations, 1982-1990

Town	Site	Cases Observed	Cases Expected*	Percent Elevation
Bourne	Female colorectal	70	46.5	60
	Female lung	70	90.4	123
	Female breast	132	90.4	46
Falmouth	Female colorectal	132	99.2	33
	Female lung	92	67.1	37
	Male leukemia	24	13.1	83
Barnstable	Total colorectal	399	311.7	26
	Female lung	146	100.0	46
	Female breast	359	288.9	26
	Total leukemia	47	34.1	38

*Expected values are calculated by MDPH using State incidence data by age group and the number of residents in each town by each age group and gender.

- Aschergrau & Ozonoff (1991) found a statistically significant association between brain cancer and swimming in the waters of Johns Pond. See ATSDR (1994:56,133) confirming the validity of this interpretation. The presence of excess brain cancer in Mashpee is supported by MDPH, 1993: significant elevation of 124% for males and females combined was observed in 1982-1990.

These data show that the Upper Cape population is vulnerable to high rates of cancers that may be associated with exposure to benzene, chlorinated hydrocarbons or hydrazine derivatives. Decisions about remediation must include the possibility that any future exposures might synergistically enhance presently observed vulnerabilities.

Residents of the region surrounding the MMR have been actively involved in reviewing the extent of toxic contamination of air and water, together with high elevations in local cancer rates. There is strong sentiment that the Federal Government display a remedial vigor appropriate to the scale of past and present military activities.

2.5 CONCLUSION

The unique features of Upper Cape Cod distinguish the area as highly susceptible to environmental pollution. Because of these features, the MMR, with its extensive and unmitigated plumes of groundwater contamination, poses a threat to the health, safety, and welfare of Cape residents and visitors.

SECTION 3.0 GROUNDWATER CONTAMINATION AND THE DEVALUATION OF PROPERTY

3.1 INTRODUCTION

In towns, cities and neighborhoods nationwide, scientific and statistical studies have documented the fact that proximity to hazardous waste sites decreases property values.

For example, a study by R. Mendelsohn, et. al., found that the actual sales prices of properties affected by pollution had fallen 7 percent to 12 percent ($7,000 to $10,000 in 1989 dollars) near the most contaminated parts of New Bedford Harbor and 3 percent to 7 percent in the next most contaminated zone. This study is particularly valuable because it measured repeat sales of individual properties over time.

A study by G. E. Smolen, et. al., in Real Estate Appraiser found a 15 percent loss of value per square foot of living space for homes within 2.6 miles of a Toledo, OH hazardous waste landfill.

Studies such as these show that hazardous waste landfills and surface water pollution decrease the value of adjacent properties. Evidence published thus far indicates that real estate markets – driven by the perceptions of prospective buyers and sellers – react similarly to groundwater contamination.

The importance of seller-buyer perception in determining real estate values is paramount. A January 1993 article in The Appraisal Journal by J. A. Chalmers and S. A. Roehr discusses the concept of "stigma" in valuing property affected by hazardous substances " ... in, on, or near the subject property in measurable quantities." The Upper Cape suffers from this stigma.

In addition, because the MMR is a 32-square-mile non-point source of various types of contamination overlying a critical sole-source aquifer, the negative impact on housing values is spread over a larger area. Plume contamination of large ponds used for boating, swimming and fishing also tends to increase the negative effects of MMR groundwater pollution on housing values.

A study conducted by McClelland, et. al., and published in Risk Analysis shows that public perception of potential health risks depresses values independent of scientific assessments. They studied an NPL-listed hazardous waste landfill located between Montebello and Monterey Park, California.

Janet Kohlhase in a July 1991 study published in the Journal of Urban Economics established that "... consumers translate the potential hazards into potentially depressed housing values." Her study showed that the further from a toxic site, the higher a property's market value: "... the price of a home would likely be higher if it were located further from a site, by as much as $3,310 per mile evaluated at the means."

According to the Kohlhase study, USEPA designation of a facility such as the MMR as a National Priorities List (NPL) Superfund site lowers home values by a predicted 15 percent at the site boundary compared to a home six miles from the site; 8 percent lower at two miles; and 2 percent lower at four miles.

"Perceived risk" can cause a dangerous "snowball effect" in a neighborhood or town: loss of property value leading to lower tax collections and fewer town services. Individual law suits brought to redress contamination problems can also cause losses to property values.

3.2 DISCUSSION

The negative impact of "perceived risk" is clearly a factor in real estate markets around Otis/Camp Edwards. As the following anecdotes illustrate, property values in neighborhoods near the MMR have been depressed by groundwater pollution, negative publicity about the pollution, and lack of cleanup activity.

- A home at 22 Cranberry Avenue, just north of Johns Pond in the vicinity of the SD-5 plume, which sold for $173,500 in 1988 sold for $102,000 in May 1992, a 41 percent plunge in actual resale price.

- A prospective buyer recently cancelled an appointment to view a house at the end of Perry Road in North Falmouth, which is threatened by the LF-1 plume, when he became aware of the plume's proximity.

- A four-bedroom house one block from the southern end of Johns Pond – not yet underlain by a plume of contamination – sold for $172,500 in 1988. In April 1993 it sold for $126,000, a 26 percent drop in sales price.

In the absence of a site-specific scientific study of local property sales and assessments, it is not possible to quantify the damage attributable to MMR groundwater pollution. However, telephone interviews with area real estate appraisers and our review of available scientific

literature regarding real estate pollution impacts support our conclusion that the MMR plumes are depressing the local real estate market.

Furthermore, statistics released by the Massachusetts Department of Revenues reveal that the assessed value of residential property in towns around the MMR has dropped significantly since 1990, a year after USEPA added the MMR to the Superfund National Priorities List. Commercial property assessments have also decreased by 34 percent in Mashpee. Massachusetts Department of Revenues statistics indicate that the average of assessed residential values State-wide has dropped 11 percent since 1990 while Upper Cape Cod values fell from 12 percent to 29 percent.

Some of the overall decrease in values can be attributed to a generally depressed housing market; however, an additional percentage could possibly be due to MMR groundwater pollution.

Here are some selected comments from an OpTech report on informal telephone interviews with local real estate appraisers:

- "... perception is value ... because of people's perceptions of the decrease in amenities (swimming and fishing), there has been an impact to property values around the ponds."

- "She [a local appraiser] said she was asked about contamination and the plumes constantly by people looking for real estate ... When asked if she felt those homes in the areas or the plumes stay on the market longer than other homes in the area, she replied in the affirmative."

- "... there is a perception of fear in the ponds area, that what you can't see can hurt you."

- "... in the Ashumet Valley, due to the [loss of] amenities associated with the ponds, and people's perception about swimming in and eating fish from the ponds, there has been some impact."

3.2.1 Simultaneous Plume Containment Can Reverse Downward Trend

The Kohlhase study also found that cleanup action leads to increasing property values. We would expect to see the same kind of recoupment of property values when a total, simultaneous containment action is underway at the MMR.

Our emphasis is on "total" and "simultaneous."

At the hazardous landfill McClelland studied – unlike the MMR – health investigations had indicated no increased cancer risks and no significant health problems. Unlike the MMR situation, ATSDR had not determined the site to be a "public health threat." Odor seemed to be the only problem associated with the landfill. Even so, "... community-wide property value losses attributable to health risk beliefs were roughly $40.2 million. Even after the site stopped accepting new waste shipments, losses attributable to health risk beliefs were still about $19.7 million."

With the uncertainties facing Upper Cape residents, business people and tourists regarding the MMR's contamination of ponds and groundwater, human health impacts and association with higher-than-State-average cancer rates, property value losses due to "health risk beliefs" are probably deeper and more widespread than at many of the hazardous waste sites studied.

B. Mundy in an April 1992 article in The Appraisal Journal states that: "When the contamination is controlled, the value of the property would be expected to increase to full market value if the public believes scientists and the public health experts." [emphasis added]

Public mistrust of the NGB and regulatory agencies can be reversed by "total" and "simultaneous" cleanup action at the MMR. In fact, it may be the only credible way to restore full public confidence and thereby increase the market value of surrounding residential properties. Partial cleanup measures probably will not be accepted by residents and tourists as sufficient to ensure public health and the integrity of our sole-source aquifer.

Also, because the MMR is an active military Base, there are ongoing negative effects to contend with – both psychological and physical, real and perceived – of jet noise and exhaust, PAVE PAWS radiation, and air, light and noise pollution from control towers, aircraft and artillery practice.

Fifteen years of reported groundwater and pond contamination has depressed residential property values in the towns abutting the MMR. It seems likely that, in spite of ongoing problems associated with MMR operations, immediate and thorough plume containment will lead to a recoupment of much of the residential property value around the MMR.

3.2.2 The Impact of MMR Contamination on Tourism; Psychological Impacts and Public Perceptions

Difficult to quantify and measure, the psychological impact of the MMR groundwater pollution on local residents and tourists is, nonetheless, important to consider in evaluating the proposal to implement a simultaneous plume containment plan. According to the Cape Cod Commission, the four towns that abut the MMR account for a significant share of Cape Cod's estimated $1 billion of tourist-related income.

While the scientific literature dealing with the impact of hazardous waste sites on the housing market is extensive, we were unable to locate studies targeting the impacts on business and tourism. It seems likely, however, that Upper Cape businesses, especially those that rely on tourism and second-home sales, have been hurt by the presence of MMR groundwater and surface water pollution. Because of widespread media coverage, many potential tourists and summer residents know of these unresolved MMR contamination problems and go elsewhere to swim, fish and vacation. A further problem for local businesses is the possibility that banks will not give mortgages.

The importance of "perception" in setting the value of properties in proximity to hazardous waste sites is well documented, as indicated previously. We believe that the psychological, perceptual impacts outlined in many studies can be extended to the behavior and mental state of tourists and residents.

Upper Cape cranberry bogs and golf courses – and there are many – use large amounts of water for irrigation. Public perceptions of risk regarding water quality around the MMR may affect consumer behavior and lead to nationwide losses in Cape Cod cranberry sales and in the number of golfers who visit Upper Cape facilities. Furthermore, in the town of Bourne alone (most likely to be affected due to the proximity of the LF-1 plume), commercial and recreational shell fishing is a $2.4 million industry with an almost $10 million economic impact on the local economy.

3.3 CONCLUSION

While fears of health and environmental risks have undoubtedly deterred potential tourists and have alarmed local residents, a credible cleanup will reverse these effects. Plume containment is vital to municipal solvency and a robust local economy.

As in the residential real estate market, tourists and residents will respond favorably to a credible cleanup plan, or, in this case, a thorough and simultaneous plume containment action. Such a response would help reclaim tourist dollars, seasonal rental income and the psychological well being of year-round residents.

SECTION 4.0 PLUME CONTAINMENT SYSTEM

4.1 INTRODUCTION

The plumes from the MMR will continue to pollute valuable groundwater resources and threaten water supplies and environmental resources if they continue to migrate unchecked. Although the IRP process is moving inexorably toward cleanup, it will be many years before cleanup is completed. An interim action has been proposed to contain the plumes as soon as possible to limit further contamination and improve the likelihood of success of the eventual cleanup. The Plume Response Plan was developed by the Plume Management Process Action Team, with Operational Technologies Corporation (OpTech) providing the Conceptual Model and cost information described in the proposed interim action.

This Conceptual Model for the interim response actions at MMR outlines the assumptions, guidelines, and the methodology used to develop a conceptual approach to plume containment in order to prepare a well supported cost estimate to justify funding by the Department of Defense. Special emphasis has been placed upon providing the documentation necessary to support the cost estimate which is an integral part of the Defense Environmental Restoration Program (DERP) programming document. Information has been included in the format necessary to support specific program elements required by the DERP when requesting funding for this key IRP activity.

4.1.1 Background

In November 1989, the USEPA placed MMR on the NPL, based on the formal investigation and identification of a variety of sources of contamination on the installation. As investigations continued, nine groundwater plumes were identified as emanating from the MMR; these plumes represent a threat to the single, sandy aquifer that is the sole source of fresh water for the Upper (Western) Cape Cod. In January 1994, the ATSDR reviewed the environmental status of the MMR and formally designated the installation a "public health hazard." A tenth plume has been tentatively identified emanating from the aviation gasoline (AVGAS) Fuel Dump Valve Test Site (FS-1) and investigations are ongoing. The nine originally identified groundwater plumes and their sources are identified in Table 4.1.

Within the IRP, the policy of the U. S. Air Force, adopted by the Air National Guard Readiness Center (ANGRC), is to "take appropriate action to eliminate eminent threat to human health regardless of whether or not they are included on the NPL."

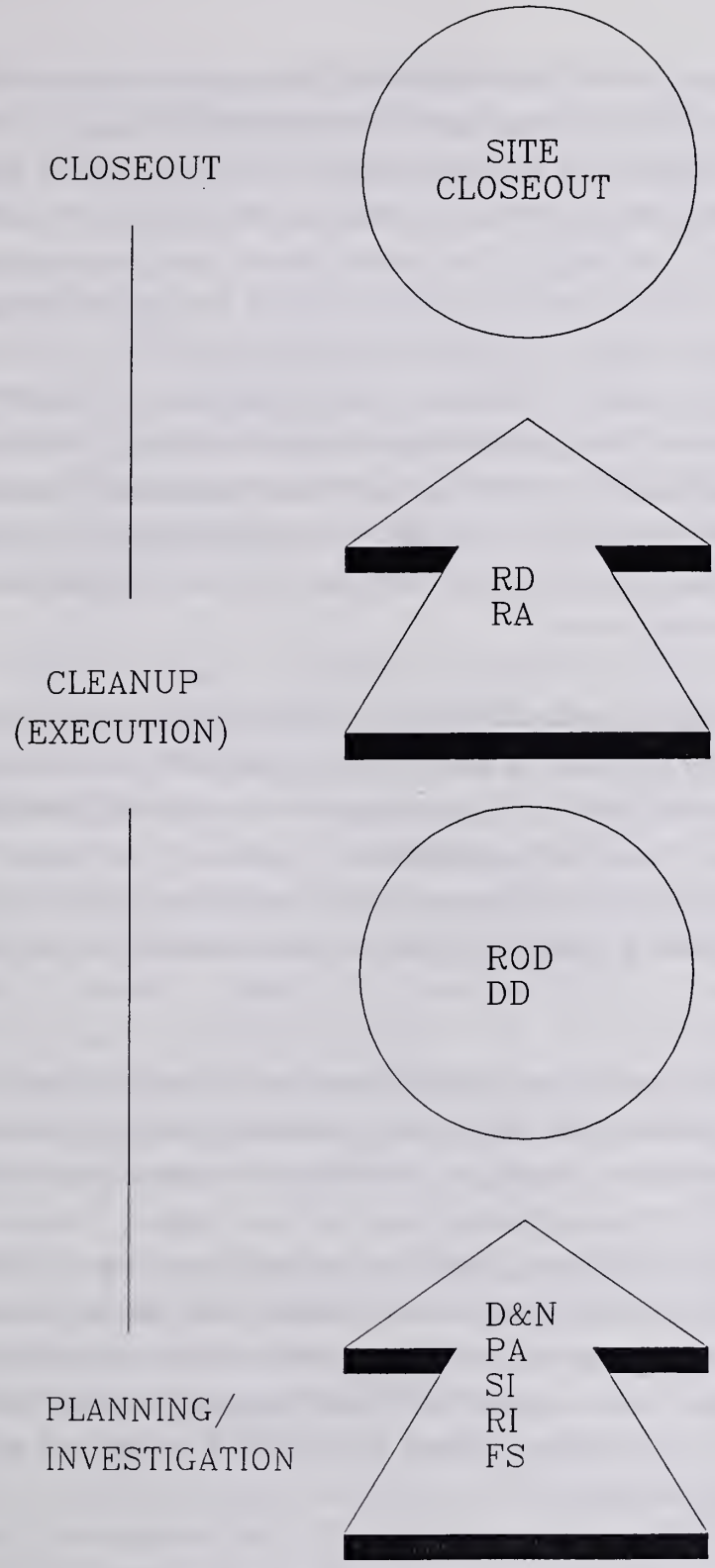
Table 4.1
Identification of Massachusetts Military Reservation Plumes

Plume Identification	Source
LF-1	Main Base Landfill
CS-10	Boeing Michigan Aerospace Research Center (BOMARC) Facility
PFSA	Petrol Fuel Storage Area (PFSA)
SD-5 (NDIL)	Storm Drain-5 (Non-Destructive Inspection Laboratory (NDIL))
Eastern Briarwood	MMR Industrial Area
Western Aquafarm	Underground Storage Tanks (USTs), Fuel Transfer System
CS-4	Motor Pool & Defense Property Disposal Office (DPDO)
Sandwich (FS-12)	Cape Cod Canal Fuel Transfer Line
FS-1	Fuel Dump Valve Test Site
Ashumet Valley (FTA-1)	Sewage Treatment Plant and Fire Training Area 1 (FTA-1)

CS – Chemical Spill.
FS – Fuel Spill.
FTA – Fire Training Area.
LF – Landfill.
SD – Storm Drain.

In order to achieve this objective, the ANGRC has established formal, systematic procedures for site cleanup and site closeout, in accordance with national level standards under CERCLA, as promulgated under a formal Federal Facility Agreement (FFA). The FFA includes a schedule of environmental activities from initial site identification to final closeout or long-range monitoring. The path by which site closeout is achieved is dependent upon data from the investigation, characterization, analysis, and supporting environmental information pertaining to each site. The IRP process is divided into "Planning and Investigation," "Execution," and "Closeout" stages (see Figure 4.1). The sites which represent the sources of contamination for the contaminated groundwater plumes are still in the "planning and investigation" stage. As a result, final site closeout may take many years.

In order to facilitate the more effective investigation and cleanup of the MMR, the ANGRC has agreed to consider an IRP management strategy intended to accelerate the site closeout process, while ensuring that citizens of the communities surrounding the MMR were kept informed and involved early in the decision-making process. The four surrounding Massachusetts communities are Falmouth, Mashpee, Sandwich and Bourne. Citizens from each of these communities were invited to participate in a new management structure to accelerate the IRP process within the MMR.



LEGEND

D&N	DISCOVERY AND NOTIFICATION
PA	PRELIMINARY ASSESSMENT
SI	SITE INSPECTION
RI	REMEDIAL INVESTIGATION
FS	FEASIBILITY STUDY
ROD	RECORD OF DECISION
RA	REMEDIAL ACTION
RD	REMEDIAL DESIGN
DD	DECISION DOCUMENT

FIGURE 4.1

R\OTIS\PROCESS

IRP PROCESS

MASSACHUSETTS MILITARY RESERVATION

OPTECH

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The new IRP management structure includes the formation of Process Action Teams (PATs), which include concerned citizens, regulatory agency representatives, and NGB managers. Three PATs were formed: Plume Management PAT, Long-Range Water Supply PAT, and an Innovative Technologies PAT. Providing general activity oversight and tasking to the PATs is a Senior Management Board (SMB), consisting of senior level regulatory agency representatives, Select persons from the four communities, the Adjutant General of the Massachusetts National Guard, and ANGRC environmental managers. Individual charters for each PAT were drafted by the SMB to provide standardized guidance. Meeting on a scheduled basis, the three PATS have considered specific environmental issues, provided regular updates on their activities to the Technical Environmental Affairs Committee (TEAC), prepared proposals for public comment and SMB review, and have held key discussions on how best to resolve contamination problems at MMR. Besides the public meetings of the SMB, the TEAC has provided a second forum for gathering information on environmental issues.

The focus of the PATs and the SMB is to achieve resolution of the contamination problems at MMR sooner than could be accomplished under the FFA schedule. The PATs were empowered to develop several proposals, including the initiation of interim actions to deal with groundwater contamination, drawing up plans to ensure safe drinking water supplies for the Upper Cape through 2020, and the evaluation of promising innovative environmental technologies. The most immediate goal, the containment of the groundwater plumes, is the responsibility of the Plume Management PAT.

After reviewing investigative reports, it was determined that there was an imminent danger from the plumes discharging into ponds, streams and coastal waters, threatening the public health and environmental quality of the Upper Cape. Significant risk to public health and groundwater resources was also identified due to threatened contamination of water supplies. Because the implementation of remediation efforts was forecasted to be several years away, it was concluded that steps had to be undertaken to stop the spread of contamination until remediation could commence. It was concluded that the quickest and most cost effective way to accomplish this was to implement a plume containment scheme which dealt with all the plumes at once. Adding a sense of urgency to the project is the continuing pollution threat to the drinking water sources for the four townships surrounding the MMR.

It was decided that a Plume Response Plan needed to be developed, initially submitted to the SMB for validation, and subsequently forwarded to the ANGRC for approval and inclusion as a valid priority 1, IRP project. The Plume Response Plan would be considered an "interim action" under the IRP and CERCLA process. Since the Remedial Investigations (RIs) for the

plumes were incomplete and Feasibility Studies (FSs) had not yet been accomplished (the only exception being the Ashumet Valley Plume), the PAT did not have sufficient technical data to develop the necessary documentation. OpTech, an NGB contractor, was tasked to provide the necessary technical assistance needed to develop this documentation.

4.1.2 Guidance

The objective of the Plume Response Plan, is to stop the migration of the contaminated groundwater plumes emanating from the MMR. Groundwater contamination refers to the presence of chlorinated solvents and fuel components, including TCE, PCE, carbon tetrachloride (CCl_4), 1,1-dichloroethene (1,1-DCE); benzene, toluene, ethylbenzene, and xylene (BTEX); metals; and EDB.

The MMR IRP process is a continuum of activities from initial site identification through site closeout. Most of the sites on the MMR have reached the RI/FS stage; however, some investigative/feasibility data has not yet been fully developed. As a result, it was recognized that the RI and FS phases were incomplete and, in turn, OpTech was provided certain guidelines for the development of a Conceptual Model to identify the technologies to be used for the IRP Plume Response Plan. Although the Conceptual Model approach was not intended to completely replace the Feasibility Studies already in progress, it was to be used in lieu of completed Feasibility Studies. Without the Conceptual Model, a cost estimate for the design and implementation of remediation projects could not be developed. The PAT requested that OpTech (1) develop a Conceptual Model for containing all of the groundwater plumes, (2) provide the necessary justification for the technologies recommended in the model, and (3) develop the associated cost estimates to implement and sustain the containment system.

OpTech was tasked to develop a conceptual plan that would accomplish containment of the plumes through the use of a series of extraction wells placed at the leading edges of each plume. The leading edge of each plume was defined from plume maps developed by Hazardous Waste Remedial Actions Program (HAZWRAP) under contract to the NGB. A map depicting the location and size of each plume is included as Figure 4.2. OpTech was also requested to provide a construction phase-in schedule for the project. In addition, OpTech was required to provide a cost estimate for a 20-year operations and maintenance (O&M) period. Conceptual Model assumptions included:

- PFSA, FS-1, and CS-4 Plumes would not be included as part of the Plume Containment Project. The PFSA is undergoing natural biodegradation, FS-1 has

FIGURE 4.2

PLUME AREA MAP

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not yet been adequately defined, and CS-4 containment has been accomplished as part of a 1993 plume containment project.

- The Conceptual Model was to be made based on the hydrogeological data available from the investigative studies conducted by HAZWRAP and its subcontractors. OpTech was not expected to conduct additional investigative studies, but to use available environmental data. OpTech therefore assumed that the geology, hydrology, and groundwater contamination have been sufficiently characterized for each plume. These data are formally reported in "Draft" or "Final" reports.

- When data gaps were encountered, OpTech would interpret available data and complete data gaps with documented assumptions.

- For the purposes of the Conceptual Model, groundwater contamination was separated into three classes; chlorinated solvents, metals and fuels.

- Total concentration of chlorinated solvents is the sum of the individual concentrations of its constituent parts. The definition of total chlorinated solvents, as depicted and defined by individual HAZWRAP plume location maps, is different for each plume, as follows:

    - *LF-1:* Defined as the total concentration of vinyl chloride (not a chlorinated solvent), TCE, PCE, carbon tetrachloride (CCl_4), 1,1-DCE, and metals.

    - *CS-10:* Defined as the total concentration of TCE, PCE, and 1,1-DCE.

    - *Ashumet Valley (FTA-1):* Defined as the total concentration of TCE, PCE, and 1,2-Dichloroethene (1,2-DCE).

    - *SD-5 (NDIL):* Defined as the total concentration of TCE, PCE, methylene chloride, and 1,1-DCE.

    - *Eastern Briarwood:* Defined as the total concentration of PCE and benzene.

- Total concentration for BTEX refers to the sum of the individual concentrations for benzene, toluene, ethylbenzene, and xylene. HAZWRAP's definition for Total BTEX for each groundwater plume is:

  - *Western Aquafarm:* Defined as the total concentration of BTEX.

  - *Sandwich (FS-12):* Defined as the total concentration of benzene. Of note, the second plume associated with FS-12 is based upon the total concentration of EDB.

- The areal extent of contamination for each plume is defined as the location where the total concentration for chlorinated solvents is 5 ppb or greater, the total concentration of BTEX is 5 ppb or greater, and the total concentration for EDB is 0.02 ppb or greater.

- Groundwater simulation of groundwater flow and particle paths would be performed by the USGS using its regional groundwater model. The model would be used to address questions concerning regional changes in water levels, streamflow, and flow directions caused by the containment scheme.

- The Plume Management PAT provided general areas where each containment well fence should be located, but OpTech was to determine whether the locations were feasible.

- HAZWRAP would furnish OpTech with the most recent maps (AutoCad or similar files) and technical data in a timely manner.

- The contaminant plumes were assumed to be located as shown in the most current HAZWRAP plume maps and IRP Remedial Investigation documents. The areal extent of the plumes, thickness of the plumes, and the subsurface locations of the plumes were assumed to be as shown in the maps.

- Commonwealth of Massachusetts or local government entities can execute the right of eminent domain for securing necessary equipment installation sites and pipeline rights-of-way.

- Electrical service would be provided to all sites as necessary.

- Topographic maps for equipment sites and proposed pipeline rights-of-way would be provided to OpTech as required.

- All necessary permits would be provided and would not create delays for the remediation contractor.

4.1.3 Approach

The technical strategy suggested by OpTech was to consider each plume as a separate entity. Applicable containment, remediation, and re-injection technologies would be used to develop an individual treatment unit (ITU) for each groundwater plume. A regional groundwater assessment would then be performed using the USGS groundwater model and the final Conceptual Model would be based on the analytical information produced by the USGS model. A unified approach, which would tie in several or possibly all the ITUs as a central treatment unit (CTU), would then be developed to treat the remediation of the groundwater plumes as an integrated process. A comparison among the different remediation approaches would then be performed. Finally, OpTech would make a recommendation to the PAT on which approach to use, based on technological effectiveness, construction feasibility, and estimated cost.

4.1.4 Program Schedules

There are two approaches to scheduling the implementation of the Conceptual Model; the first is the normal linear scheduling process under the Installation Restoration Program and the second is an accelerated schedule involving simultaneous activities.

4.1.4.1 Normal IRP Schedule

The "normal" IRP schedule of required activities to implement the Conceptual Model involves a 72-month period. Assumptions include the normal periods for project contracting, follow-on contractor selection, work plan construction, environmental management and regulatory agency review periods, field work and resultant analytical reports, follow-on contracting periods for required remedial activities, and required work plan construction and regulatory and public review cycles. The 72-month period does not allow for delays due to weather, headquarters or regulatory reviews, or delays due to contractor activities. The schedule also assumes a sustained level of financial support through the DERP. Figure 4.3 depicts the normal 72-month IRP schedule.

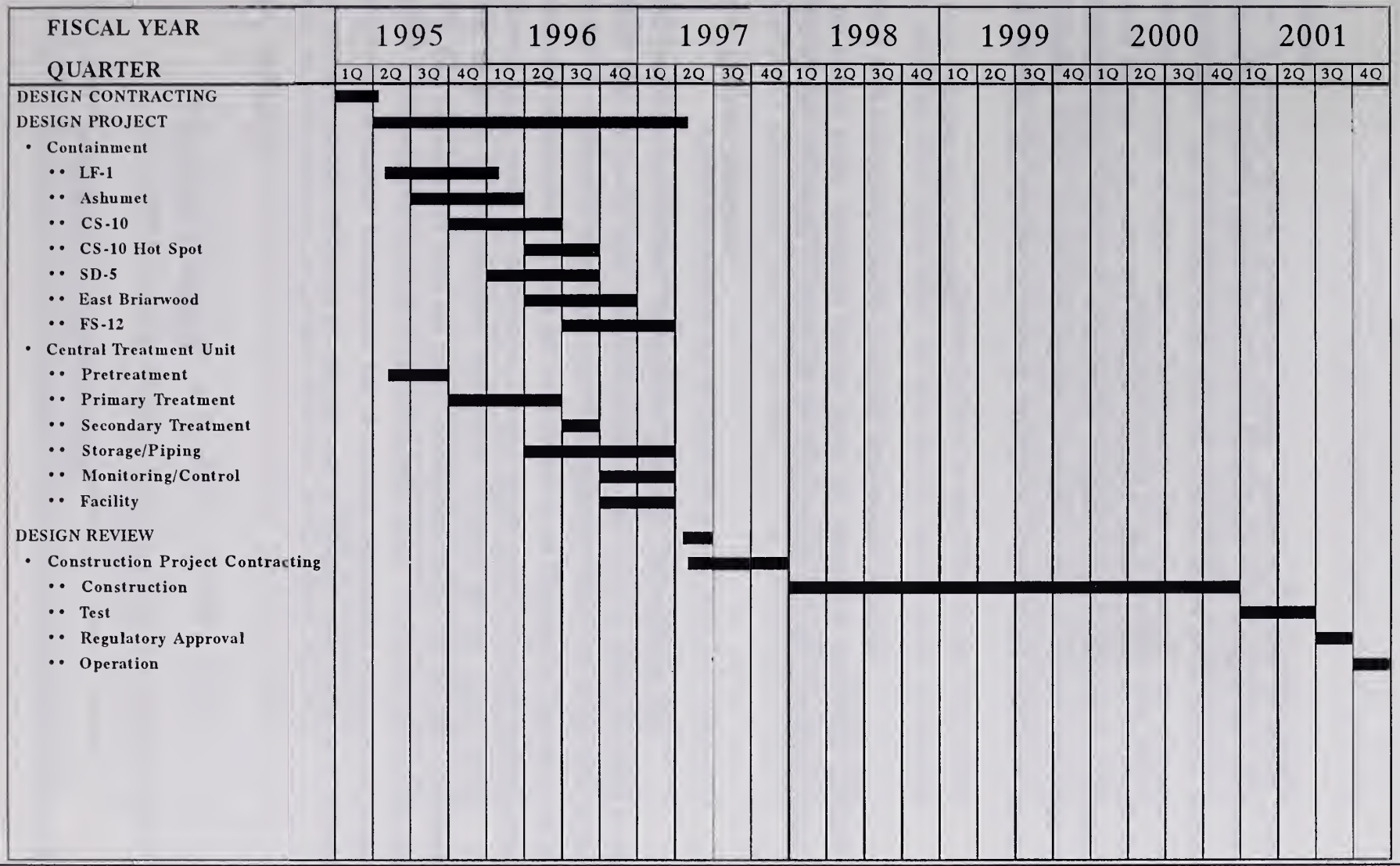

Figure 4.3

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NORMAL PROGRAM SCHEDULE
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4.1.4.2 Accelerated Schedule

The accelerated schedule of environmental activities to contain the groundwater plumes was prepared to depict a 42-month period of performance in which the treatment system and one plume well fence would be in operation. Accordingly, an accelerated contracting period is also required, as well as several simultaneous and overlapping activities associated with the construction of the plume containment system. For example, in contrast to the normal IRP schedule, contracting for the entire project must be accomplished within a 60-day period. Figure 4.4 depicts the 42-month accelerated implementation (contracting, design and review) schedule.

This schedule is extremely optimistic, and may not be realistic for a project of this magnitude. Review periods may need to be increased to ensure that a sound design is produced.

4.1.4.3 Accelerated Construction Schedule

In order to meet the proposed schedule to implement the Conceptual Model, a corresponding proposed schedule of specific construction activities must be accomplished. Whereas "normal" execution of construction actions would be conducted in a sequential fashion, the accelerated construction activities would be conducted in a rapid, simultaneous, overlapping schedule. Accordingly, the accelerated construction schedule for the Conceptual Model is shown in Figure 4.5. Specific construction activities associated with the well fences and the construction of a central treatment unit are included.

4.2 PLUME DESCRIPTIONS

This section summarizes the regional geology and hydrogeology in the study area, describes the plumes of concern and source areas, and provides an overview of the groundwater modeling approach that supports the Conceptual Model as a feasible means of stopping further migration of the groundwater plumes. The regional geology and hydrogeology are described in detail in a 1989 hydrogeologic summary report (E. C. Jordan Co., 1989).

4.2.1 Geology

The geology of western Cape Cod is dominated by glacial sediments deposited 7,000 to 85,000 years ago. During that period, geologic evidence suggests that two adjacent glacial lobes of the Wisconsin ice sheet provided meltwater for glaciofluvial sedimentation in a preglacial

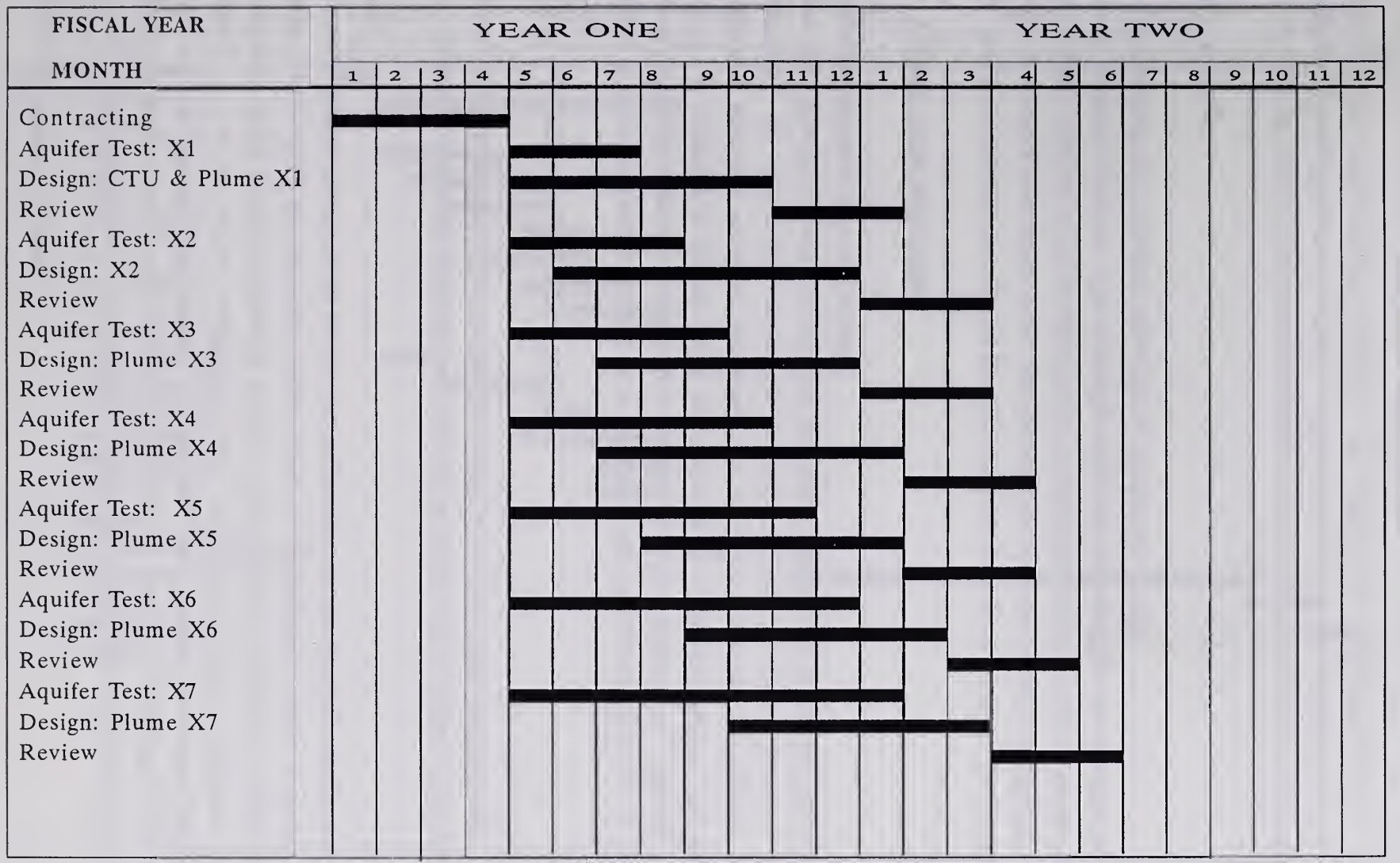

Figure 4.4

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ACCELERATED DESIGN SCHEDULE
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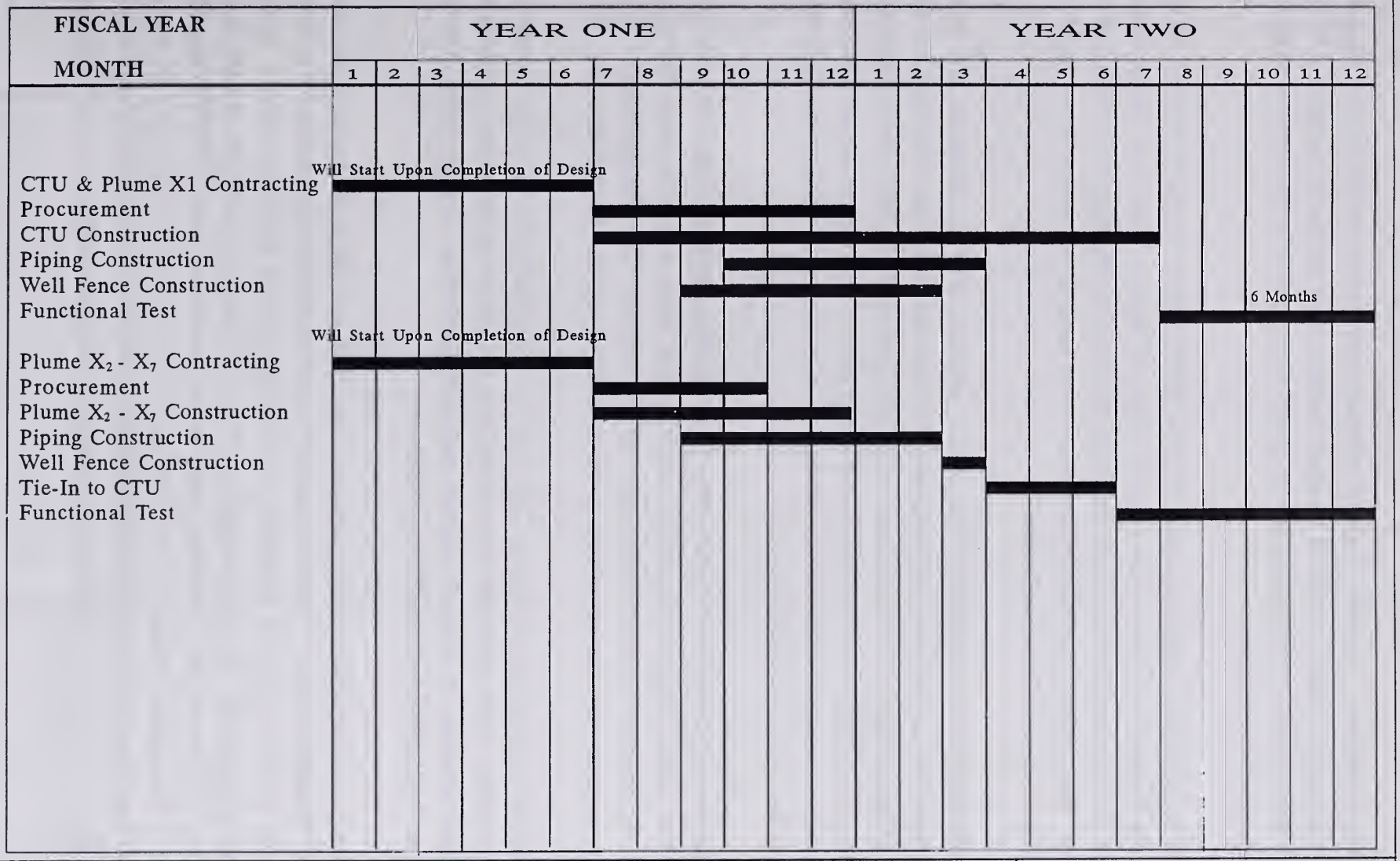

Figure 4.5

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ACCELERATED CONSTRUCTION SCHEDULE
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depositional environment. A series of glacial advances and retreats resulted in outwash and lacustrine sedimentation based on fluvial transport distance from the glacial margin. After a hiatus from fluvial activity, a re-advance of both glacial lobes resulted in deposition of terminal moraines on top of the outwash.

As a result, two moraines, the Buzzards Bay Moraine (BBM) and the Sandwich Moraine (SM), were deposited along the western and northern edges of western Cape Cod, respectively. Between the two moraines lies a broad outwash plain, known as the Mashpee Pitted Plain (MPP) (Figure 4.6). Fine-grained, glaciolacustrine sediments and basal till are present below the MPP at the base of the unconsolidated sediments.

The total thickness of unconsolidated sediments (i.e., moraine, outwash, lacustrine, and basal till) is estimated to increase from approximately 175 feet near the Cape Cod Canal in the northwest to approximately 325 feet beneath the thickest portion of the BBM; it then decreases to approximately 250 feet near Nantucket Sound in the south. Thickness of the MPP outwash sediments ranges from approximately 225 feet near the moraines in the north to approximately 80 feet near the shore of Nantucket Sound.

The regional geology is dominated by three extensive sedimentary units (i.e., the BBM, SM and MPP). These glacial materials are areally extensive and, while containing some fine-scale variability, the macroscale characteristics are relatively uniform. The characteristics of each sedimentary sequence have distinct effects on the behavior of regional groundwater flow.

The depositional environment of western Cape Cod was controlled by fluvial processes related to glacial activities. MPP sediments were carried from the glaciers by meltwater, resulting in poorly graded sediments of relatively uniform grain-size distribution. Poorly graded outwash sediments are typically very permeable to groundwater.

The western part of the MMR overlies portions of the BBM and SM in the northern part, and the MPP to the south and east. The BBM and the SM were deposited at the glacial ice margin. Little fluvial transport occurred; therefore, the sediments tend to be poorly sorted. While well-graded sediments are often characterized by low permeability to groundwater, the moraines on the Western Cape are thin, overlying highly sorted outwash sediments. In addition, the percentage of fine-grained sediments in the BBM and the SM is lower than many end moraines. This means that the permeability of BBM and SM sediments, while lower than the outwash, is relatively high. In addition, preliminary data suggest that these moraines may be thin and

SOURCE: HAZWRAP GROUNDWATER REMEDIATION STRATEGY REPORT, 1992.

FIGURE 4.6

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REGIONAL SURFICIAL GEOLOGIC MAP
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overlie outwash sediments. In this case, most of the saturated thickness of the aquifer would be outwash sediments (E. C. Jordan Co., 1989).

Over much of western Cape Cod, the MPP is a well-sorted, stratified sand and gravel. On a regional scale, this sedimentary unit is relatively homogeneous. However, local examination of single borings or small areas on MMR indicated that local geologic variations or heterogeneities are present within the MPP (E. C. Jordan Co., 1989). The presence of geologic heterogeneities, especially variations in grain size, results in variations in the permeability of sediments to groundwater. Lenses of fine-grained sediments are present within both the MPP and BBM, which may cause variations in aquifer hydraulic conductivity in the areas of individual disposal or spill sites.

The MPP sediments, and those beneath the BBM, were observed to be stratified. Stratification of geologic material may cause anisotropy (i.e., directional variability) in hydraulic conductivity. This means that in areas where stratification is detected within the aquifer, horizontal hydraulic conductivity is likely to be greater than vertical hydraulic conductivity. The degree of anisotropy is typically influenced by the presence of fine-grained sediments within the strata. Because of the paucity of silt in the MPP sediments, anisotropy within the MPP may not be as high as would be expected from the observed stratification.

4.2.2 Hydrogeology

The Cape Cod aquifer underlies western Cape Cod, including MMR. The aquifer system is unconfined (i.e., in equilibrium with atmospheric pressure), and is recharged by infiltration from precipitation. The high point of the water table, or the top of the groundwater mound within the western Cape Cod groundwater system, is located beneath the northern portion of MMR. Flow is generally radial from this mound (Figure 4.7). The ocean forms the lateral boundary of the aquifer on three sides, with groundwater discharging into Nantucket Sound on the south, Buzzards Bay on the west, and Cape Cod Bay on the north. The eastern boundary of the flow system is a groundwater divide east of the town of Sandwich.

The total thickness of the aquifer is difficult to define because of the gradual transition from coarse- to fine-grained sediments with depth. Beneath the northern MPP and the moraines, the coarse-grained sediments extend to an approximate depth of 350 feet below land surface (BLS). Beneath the southern MPP (including most of southern MMR), coarse-grained sediments extend up to 200 feet BLS. Below this depth, significantly finer-grained sediments that may be of lacustrine origin are present. Hydraulic conductivity of these fine-grained sediments is 10 to 50

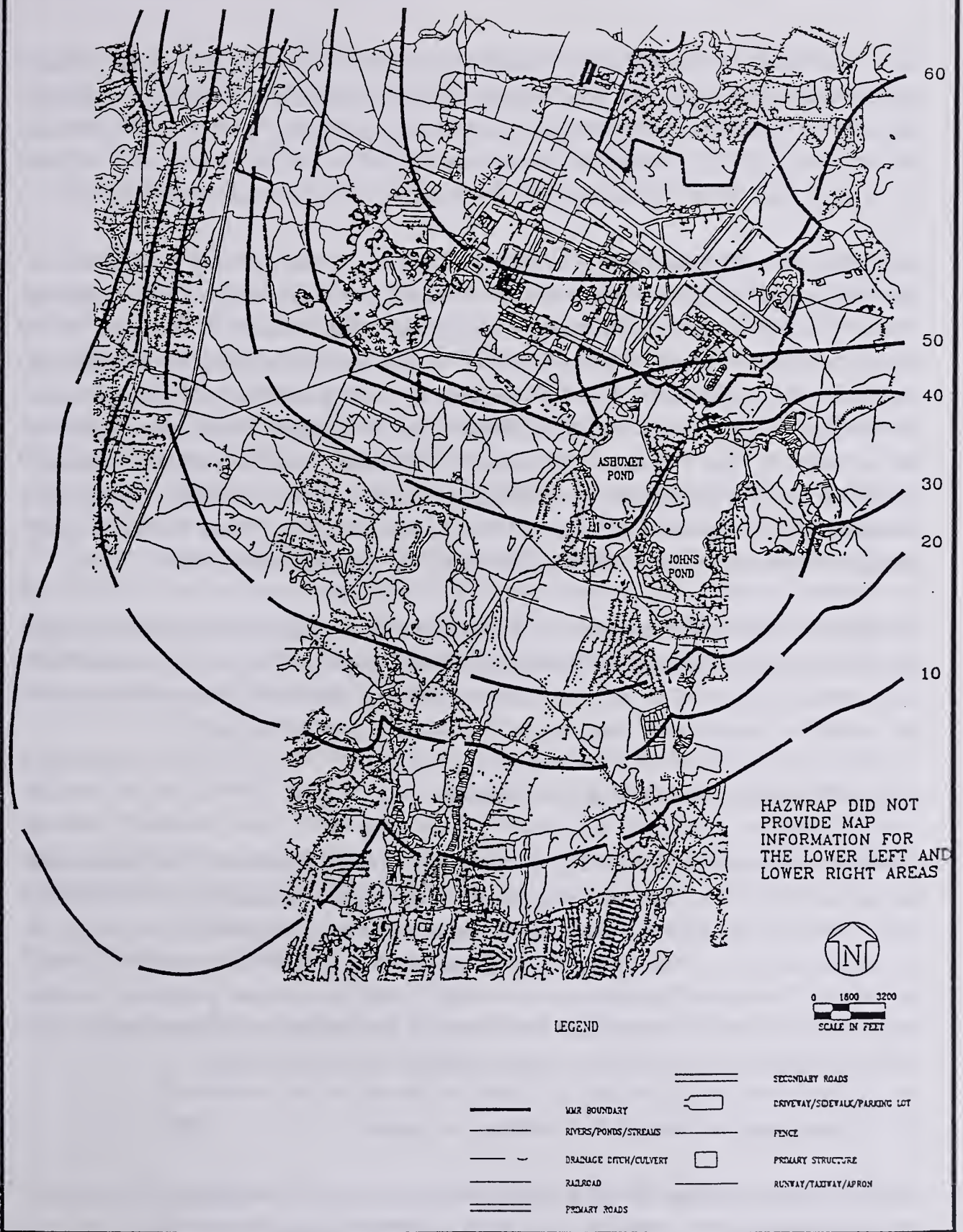

FIGURE 4.7

R:\HAZWRAP\OTIS-MAP

REGIONAL WATER TABLE MAP

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times lower than the outwash (E. C. Jordan Co., 1989). For most contamination-related groundwater investigations, this finer material may be considered the bottom of the aquifer. Therefore, in the southern MPP, the aquifer thickness is approximately 200 feet in the north and 80 feet in the south. It is important to recognize that, due to the order-of-magnitude higher permeability, the bulk of groundwater flow is transmitted through the upper outwash unit.

Kettle hole ponds are common on the MPP. These ponds are depressions of the land surface below the groundwater table which, on a regional scale, influence the direction of groundwater flow in a manner similar to large aquifer heterogeneities. The influence of water table ponds on the horizontal groundwater flow regime is most evident in the strong changes in the slope and direction of the regional water table near Ashumet and Johns ponds, two of the largest ponds on western Cape Cod. For example, groundwater flow near Ashumet Pond is characterized by vertical gradients that indicate a "flow-through" condition. Groundwater flow recharges Ashumet Pond in the northern end and discharges to the aquifer in the southern end. Johns Pond is characterized by surface water discharge (i.e., the Quashnet River). These two ponds typify the kinds of groundwater interactions observed for kettle hole ponds on the MPP.

The ponds are expected to influence the vertical component of groundwater flow within the aquifer just as they influence the horizontal components. The kettle hole ponds of western Cape Cod penetrate only part of the 80- to 200-foot-thick aquifer. However, the hydraulic influence may extend to a depth greater than the pond bottom (E. C. Jordan Co., 1989).

4.2.2.1 Horizontal Groundwater Flow Velocity

Consistent with the variation in geology across the site, hydraulic conductivity and porosity data indicate that groundwater flow velocities change with geologic environment (E. C. Jordan Co., 1989). Data from the MPP outwash material suggest a maximum groundwater flow velocity of 3.4 feet per day (ft/d). Flow through the main part of southern MMR is expected to be closer to 1 to 2 ft/d. Horizontal groundwater flow velocity within the moraines is estimated to range from 0.07 to 0.6 ft/d. Groundwater flow velocities in the moraine are slower than in the outwash, primarily due to the lower hydraulic conductivity of the moraines.

4.2.2.2 Horizontal vs Vertical Flow Within the Aquifer

Multi-level cluster wells in the MMR vicinity were used to assess the variability of piezometric head versus depth in the aquifer. In most wells, the difference in piezometric heads in the top 100 feet of the aquifer is approximately 0.05 foot or less (E. C. Jordan Co., 1989). Variations

in head seldom show a persistent increase or decrease with depth; more commonly, it is a fluctuation, with the highest or lowest values in the middle portion of the outwash. The influence of these minor vertical head variations is not expected to be significant over long travel distances. Local variability tends to be averaged with time and distance; therefore, large-scale groundwater movement may be described by simple horizontal Darcian flow.

Certain geologic or hydrogeologic conditions exist where piezometric variations exceed 0.05 foot and show a directional change with depth; these conditions are related to ponds or changes in geologic strata. In these locations, upward or downward gradients appear to be significant and persistent over time. Two well clusters on the upgradient and downgradient edges of Ashumet Pond show vertical gradients within the top 40 to 50 feet of the aquifer. The calculated gradients (i.e., 0.001 feet per feet (ft/ft) upward near the upgradient edge of Ashumet Pond and 0.005 ft/ft downward near the downgradient edge) suggest that the pond induces vertical flow in the aquifer. Similarly, well clusters on the upgradient edge of Johns Pond show an upward vertical gradient of approximately 0.02 ft/ft. The vertical gradients measured in these wells are of a similar or greater magnitude than the horizontal gradient in the aquifer. These gradients are sufficient to cause groundwater flowing at depth below the water table to discharge to Ashumet and Johns ponds (E. C. Jordan Co., 1991a). Inducement of vertical hydraulic gradients near surface water bodies is common in glacial terrain, and is expected to occur at a similar magnitude near large ponds and rivers.

Assessment of flow in the MPP sediments, as traced by chemicals dissolved in groundwater, indicates that groundwater flowpaths dip gradually into the aquifer rather than following a completely horizontal path. This is generally attributed to the accretion of rainwater recharge at the aquifer surface rather than density differences between clean water and water containing dissolved chemicals (E. C. Jordan Co., 1989).

4.2.2.3 Summary of MMR Hydrogeology

The local groundwater flow regime may be summarized as follows (E. C. Jordan Co., 1989):

- The primary aquifer material at MMR is a well sorted sand and gravel of the MPP.

- Groundwater flow is generally southward (with the exception of LF-1 which flows to the west and southwest) within these sediments at velocities ranging from 1.0 to 3.0 ft/d.

- Rainfall recharge is observed to cause groundwater flow to gradually sink into the aquifer, although the flow regime is predominantly horizontal.

- While horizontal groundwater flow dominates, vertical groundwater flow driven by piezometric head differences is limited to areas near ponds, and is influenced by lower vertical hydraulic conductivity in the stratified outwash deposits.

4.2.3 Approach to Identification of Groundwater Contamination and Plume Descriptions

Numerous inorganic and organic contaminants were detected during MMR groundwater contamination investigations. In some cases, detection of contaminants at a particular sampling location was intermittent or showed seasonal fluctuation. A comprehensive regional description of groundwater contamination on a single map is the basis of the Groundwater Remediation Strategy (GRS), and required a common definition of contaminant characterization.

For the purposes of this report, groundwater contaminants are separated into three classes: solvents, metals, and fuels. Solvent contamination is defined as the summation of the four most commonly occurring chlorinated solvent groundwater contaminants at MMR: PCE, TCE, DCE, and CCl_4. Metals contamination primarily refers to iron, but may include other metals such as arsenic and lead. Fuel contamination is defined as the summation of the four most commonly occurring fuel components at MMR: BTEX plus a common fuel antiknock additive, EDB. Concentration contours were established at 5, 20, and 100 ppb contaminants for both solvent and fuel plumes.

The following subsections briefly describe site-specific source areas and the resulting groundwater contamination. The information was summarized from ongoing or completed RI reports; more detailed information on specific study areas is in the referenced reports.

4.2.3.1 Sandwich (FS-12) Plume

According to Advanced Sciences, Inc. (December 1993), the origin of groundwater contamination and free product was a leak in a section of fuel pipeline at the intersection of Greenway Road and the western entrance to L-range. Both AVGAS and JP-4 jet fuel were released. The leaking section of the pipeline was repaired in 1972. Fuel leaking from the pipeline contaminated soil in the immediate vicinity of Greenway Road and groundwater downgradient for a distance of about 5,000 feet. Free product was found in the vadose zone over a 5-acre area north and south of Greenway Road. Except for small pockets of benzene,

the primary soil contaminants were toluene and xylenes with lesser quantities of ethylbenzene. No EDB was reported from the analysis of soil samples collected in the unsaturated zone or in samples of free product. Fuel-related groundwater contamination was found from the source area southward to a monitoring well, located south of the entrance road to Camp Good News (CGN). Because of their potential risk to human health, the distribution of benzene and EDB is discussed separately, but the contaminated groundwater samples also contained quantities of ethylbenzene, toluene, xylenes, naphthalene, and 2-methylnaphthalene as well as a variety of tentatively identified compounds (TICs). The highest concentrations detected during CLP analysis for benzene and EDB were 1,600 and 597 ppb, respectively. Chloroform and a variety of naturally occurring inorganic compounds were detected, but the distribution of these compounds does not match that of the fuel contamination. Groundwater samples from six wells were analyzed for compounds associated with explosives. Except for a single detection of tetryl in one well, all groundwater samples were free of this form of contamination.

The fuel-related contamination is currently approaching the southern boundary of CGN. The leading edge of the benzene contamination at concentrations of 5 ppb or higher is located slightly north of the entrance road to CGN. The leading edge of groundwater contaminated with EDB at a concentration of 0.02 ppb or greater extends south of CGN Road. The groundwater appears to be moving south-southeast toward J. Braden Thompson Road.

The FS-12 Study Area features areas of low relief bounded by areas of gently rolling (hummocky) terrain. Intermittent marshes occur in low-lying areas, particularly in the northwest portion of CGN. Elevations range from 68 feet to 168 feet mean sea level (MSL). Elevations generally increase north-northwestward toward MMR. The highest topographic area is a north-south trending ridge extending from CGN, east of Snake Pond, to the Greenway Road area of MMR. Elevations decrease laterally away from this high, particularly toward Snake Pond. The mean elevation of Snake Pond is 68 feet MSL. The maximum pond depth is estimated at 30 to 35 feet.

Snake Pond is the only permanent body of surface water in the immediate vicinity of the investigation area. Peters, Pimlico, and Wakeby/Mashpee Ponds are located approximately 1 to 1.5 miles to the east-southeast. No flowing streams or rivers are located in the area. Some storm flow drains into intermittent marshy areas, located in topographic lows. Surface runoff is minimal due to high permeability surface soils and substrata.

The Sandwich investigation site is located entirely within the MPP. The geology of the site is typical of the MPP. Previous investigations and recent subsurface data indicate that the substrata

consists of outwash sands and gravels with discontinuous lenses of fine sand, silt, and clay down to at least a depth of 130 feet below the water table. Data regarding underlying basal sediments and bedrock in the area is not available.

The Sandwich area of investigation is underlain by the Cape Cod Aquifer. Locally, the sands and gravels of this aquifer serve as a primary water source for municipal and residential water supply wells. The aquifer is unconfined, with an average depth to water of 70 feet. The water table is exposed at the surface in Snake Pond, delineating the southwestern boundary of the study area.

As seen in Figure 4.2, the plume is approximately 5,000 feet long and 2,500 feet at its widest (HAZWRAP map, 1994). Expanded site investigation data indicated a horizontal flow gradient range of 0.00025 to 0.0004 ft/ft to the south-southeast (Hydrogeologic, 1992). This range is one order of magnitude lower than data previously reported from adjacent areas of MMR (ABB-ES, 1992b). Based on these measured data, an estimated horizontal hydraulic conductivity of 300 ft/d, an estimated porosity of 30 percent and horizontal flow velocity of 0.4 ft/d were indicated. The validity of groundwater flow rates based on measured gradient alone is limited. Local and regional aquifer characteristics are presented in the groundwater modeling report by HydroGeologic, Inc. (HydroGeologic, 1992).

4.2.3.2 LF-1 Plume

According to ABB-ES (October 1992), a chlorinated solvent plume dissolved in groundwater has been identified originating from the Main Base Landfill. The predominant VOCs that compose the plume are chlorinated ethenes (i.e., DCE, TCE, and PCE) and CCl_4. Additional chlorinated VOCs detected less frequently in the plume include vinyl chloride, 1,1-dichloroethane (DCA), TCA, and 1,1,2,2-tetrachloroethane. Total contaminant concentrations up to 200 ppb were measured 2,500 feet downgradient of the Post-1970 Cell. Groundwater MCLs for TCE, PCE, and CCl_4 were exceeded within the Main Base Landfill and at downgradient locations. The MCL for vinyl chloride was exceeded in one monitoring well immediately downgradient of the 1970 Cell. The vertical distribution of contaminants suggests that the solvent plume is sinking at a rate between 1.25 and 2.5 feet per 100 feet of horizontal migration, with the rate declining with increasing distance from the main landfill. Contaminants have been detected to a depth of 100 feet into the aquifer. The western boundary of the plume has not been fully defined, and the potential exists for historic groundwater contamination at some distance from older landfill cells. This zone of contamination, if present, would extend west from the main landfill.

As indicated on Figure 4.2, the plume is approximately 16,500 feet long, up to 6,000 feet wide and 80 feet thick (HAZWRAP maps, 1994). The average horizontal flow velocity is calculated to be 1.49 ft/d based upon the hydraulic conductivity of 280 ft/d (ABB-ES, March 1992). The general shape of the plume probably reflects contaminants released from different landfill cell areas active during different periods. The Main Base Landfill has been in operation since 1944, with disposal activities occurring in five distinct cells and a natural kettle hole. The total area of the solvent plume appears to be a composite of contaminants originating from the 1970 Cell and Post-1970 Cell areas of the landfill. Contaminants from the older 1970 Cell, active between 1958 and 1970, or the Post-1970 Cell would make the maximum age of the plume 20 to 32 years.

Fuel-related hydrocarbons were also detected immediately downgradient of the Post-1970 Cell and 1970 Cell areas. Aromatic hydrocarbons detected included BTEX and chlorobenzene. Maximum total concentrations of aromatic VOCs detected in the Post-1970 Cell and 1970 Cell were 142 and 14 ppb, respectively. The MCL for benzene was slightly exceeded in one monitoring well at each cell area. Dissolved aromatics have been distributed up to 75 feet below the water table at these locations; however, recent RI data indicate that fuel-related contamination may extend to only half that depth. The aromatic hydrocarbon plume does not appear to be moving any appreciable distance downgradient from the landfill. The observed BTEX contaminant distribution is believed to be influenced by the relatively high biodegradability of these compounds in the subsurface environment compared to the chlorinated solvents.

4.2.3.3 CS-10 Plume

According to ABB-ES (October 1992), the CS-10 Study Area is approximately 38 acres in size and is located at the northern edge of the MMR industrial complex, west of Snake Pond. A BOMARC ground-to-air missile defense system was operated at the CS-10 Study Area from 1960 to 1973 by the 26th USAF Air Defense Squadron. The BOMARC facility maintained approximately 56 launcher systems in a state of operational readiness. From 1978 to the present, the abandoned missile facility has been utilized to store and maintain more than 350 armored and wheeled vehicles by the Unit Training Equipment Support (UTES) shop and other Army National Guard (ARNG) organizations (ABB-ES, 1992).

BOMARC missile maintenance, power generation and fuels handling, and UTES vehicle maintenance activities at the CS-10 Study Area, have resulted in contamination of on-site soils, sediments and groundwater. Primary sources of contamination were spillage of chemicals from

underground storage tanks (USTs), leaching wells and oil interceptors where chemicals were disposed. Primary site contaminants are TCE, PCE, 1,1,1-trichloroethane (TCA), methylene chloride, No. 2 fuel oil, polychlorinated biphenyls, and waste oils.

Explorations downgradient of the CS-10 Study Area characterized groundwater quality between the CS-10, LF-1, and CS-4 study areas, and the MMR eastern boundary. The CS-10 Plume in this area contains DCE, TCE, and PCE. Historically, other Target Compound List (TCL) organic and inorganic constituents were detected in the CS-10 Plume, including methylene chloride, benzene, vinyl acetate, 1,1-DCE, 1,1,1-TCA, toluene, naphthalene, 2-methylnaphthalene, chromium, and lead.

As of 1994, the CS-10 Plume is estimated to be 12,500 feet long, up to 3,600 feet wide (Figure 4.2) and 40 to 80 feet thick (HAZWRAP maps, 1994). The plume has sunk below the water table with distance from the site, and the top of the plume is located 55 feet below the water table at Gaffney Road. Groundwater velocities in the CS-10 Plume area are approximately 0.88 ft/d (CDM, November 1993). The CS-10 Study Area RI report discusses the extent of the CS-10 Plume in detail up to the area where monitoring wells have been installed (E. C. Jordan Co., 1991g).

4.2.3.4 Ashumet Valley Plume

According to ABB-ES (October 1992), the Ashumet Valley Plume appears to be the result of two sources. The sewage treatment plant (STP), which began operation at MMR in 1936, was the most likely source in the past. The inactive Fire Training Area, located north of the STP, also contributed to the Ashumet Valley Plume. Activities at FTA-1 included pouring spent fuels and solvents onto the ground and igniting the liquid for fire fighting exercises. Solvents that were not burned completely remain in on-site soils, leaching to groundwater beneath the FTA-1 Study Area. VOCs have not been routinely disposed of in the STP since the 1970s (E. C. Jordan Co., 1987a). Sampling from wells near the STP and the FTA-1 Study Area demonstrates that the FTA-1 Plume continues to be a source of these chlorinated solvent chemicals. Chemicals from the FTA-1 Plume appear to be following the same migration flowpath as the larger Ashumet Valley Plume. Therefore, all contaminated groundwater in or immediately upgradient of Ashumet Valley is considered a single plume in the GRS, regardless of the source.

The constituents of greatest concern are PCE, TCE, and DCE, which have been detected at concentrations up to 982, 95, and 1,200 ppb, respectively. Average concentrations sampled from wells in the central portion of the plume are 60, 17, and 85 ppb, respectively.

The plume of groundwater with total PCE, TCE, and DCE concentrations greater than 5 μg/L (the MCL for TCE and PCE) is approximately 18,750 feet long (Figure 4.2). Along most of the valley, the plume is 4,000 feet wide and between 70 and 80 feet thick (HAZWRAP maps, 1994). Groundwater velocities in the area are calculated to be 2.7 ft/d (E. C. Jordan Co., 1991). As a result of rainwater accretion, the plume is migrating nearly 40 feet below the water table throughout most of its length. Near the FTA-1 Study Area, the plume is located at the water table; near the STP, it migrates deeper into the aquifer due to infiltration of approximately 250,000 gallons per day of treated wastewater (E. C. Jordan Co., 1991e).

4.2.3.5 SD-5 and Western Aquafarm Plumes

According to ABB-ES (October 1992), the SD-5 Study Area investigation was divided into the following four operable units (E. C. Jordan Co., 1990b):

- SD-5A is a point source at the former site of the NDIL.
- SD-5B is a series of USTs/fuel transfer system, known as the Western Aquafarm.
- SD-5C is located 1,000 feet south-southeast of SD-5B (the Western Aquafarm). SD-5C is an installation similar to SD-5B, and is known as the Eastern Aquafarm.
- SD-5D is the impacted groundwater zone attributable to source area Operable Units A, B, and C. Tank flushings from Operable Units B and C were directed to a permanent drainage swale midway between them, creating potential for a relatively wide combined source area. The NDIL source is a dry well, hydraulically positioned nearly upgradient of SD-5C.

A site inspection found that groundwater beneath and downgradient of the NDIL sump is contaminated with chlorinated solvents (i.e., 1,2-DCE and TCE) in excess of Federal MCLs (E. C. Jordan Co., 1990a). As seen in Figure 4.2, the plume is approximately 10,000 feet long, 500 feet wide and 20 to 30 feet thick near the source and slowly broadens to a width of approximately 800 feet as it migrates southward with the flow of groundwater, to a width of 1,750 feet as it turns easterly toward Johns Pond (HAZWRAP maps, 1994). The average horizontal flow velocity is calculated to be 4.4 ft/d (ABB-ES, 1992).

Groundwater downgradient of the Western Aquafarm contains fuel-related TCL organic chemicals (primarily toluene and xylenes). As seen in Figure 4.2, the plume is approximately 2,000 feet long and 800 feet wide (HAZWRAP maps, 1994). The thickness has not been documented (ABB-ES, Oct 1992). The groundwater velocity is 2.5 ft/d (ABB-ES, Nov 1993).

Groundwater contamination downgradient of the Eastern Aquafarm consists primarily of TCE and PCE, with sporadic fuel-related compounds. These solvents may have originated from the NDIL source, because they were not documented in fluids stored in the Eastern Aquafarm tanks. It is currently unclear if the Eastern Aquafarm has caused appreciable contamination which is separate from the NDIL contamination. The two recognizable plumes (NDIL and Western Aquafarm) originating from SD-5 sink beneath the water table during the initial 2,000 feet of travel downgradient. The top of the NDIL solvent plume is approximately 40 feet below the water table at South Outer Road (3,500 feet downgradient), and the Western Aquafarm xylene plume top is approximately 15 feet below the water table (2,500 feet downgradient). The combined plumes appear to attain a thickness of 20 to 30 feet in the unconfined MMR aquifer.

Both the NDIL and aquafarm source areas discharged contaminants to surficial soils during the 1950s and 1960s. Therefore, contaminants may have moved downgradient at approximately the velocity of natural groundwater flow for 30 to 40 years. Contaminants may have travelled 18,000 to 24,000 feet, or more than twice the distance required to reach Johns Pond in that period of time. The investigation to assess the boundaries, destination, and fate of the plumes is continuing. While the on-base flowpaths of both plumes are well defined, the off-base flowpaths are more complex due to the influence of ponds and bogs (E. C. Jordan Co., 1991d).

4.2.3.6 Eastern Briarwood Plume

According to ABB-ES (October 1992), a solvent plume (PCE and TCE) was detected beneath the industrial complex in the southeastern MMR area migrating southward toward Johns Pond. Its flowpath is mapped as passing through the Eastern Briarwood development, where shallow domestic water wells have been replaced by imported public water because of solvent contamination.

The shallowest contamination in this apparently multilayered plume is believed to originate in the SD-3/FTA-3 Study Area, located approximately a half-mile north of Johns Pond. The Phase 1 Records Search disclosed that various solvents were used in the area of former Building 165 (just upgradient of the FS-25 Study Area) for aircraft cleaning (E. C. Jordan Co., 1986). The

period of contaminant introduction into soils in the upgradient area, which also may include the FS-25 and CS-14 study areas, is believed to span the mid-1950s through the 1960s.

Sufficient data have not been collected to verify the distance of travel of the plume. Theoretically, the rate of natural groundwater movement should be sufficient to have transported contaminants to Johns Pond, considering the likely age of probable sources. The residential well contamination in the 1980s may indicate passage of the plume front.

As seen in Figure 4.2, the plume is approximately 2,500 feet long, 1,200 feet wide, and 20 feet thick (HAZWRAP maps). The plume is shallow with slowly sinking contaminated groundwater 15 to 20 feet below the water table at the farthest downgradient monitoring wells intersecting the plume for which laboratory sample results are available. Evidence of solvents at low concentrations at a depth of 55 feet below the water table has been documented (E. C. Jordan Co., 1991b). Site-specific hydrogeologic data for the Eastern Briarwood Plume is insufficient (ABB-ES, January 1993). Based upon data for the southern MMR area, the gradient for groundwater is 0.0018 ft/ft; hydraulic conductivity is 380 ft/d, resulting in a groundwater flow velocity of 2.88 ft/d (ABB-ES, 1992).

4.2.4 Plume Modeling

The Water Resources Division of the USGS, Massachusetts-Rhode Island District, has conducted the most extensive study, to date, of the Western Cape Cod aquifer. The USGS has developed a regional groundwater flow model and particle-tracking routine for the Air National Guard (ANG) to improve the understanding of groundwater flow and contaminant migration near the MMR.

The USGS was furnished proposed pumping rates from OpTech for the model cells which lie within the projected flowpath for each of the advancing plumes. Each model cell is 660 feet by 660 feet on a side, and the model is divided vertically into 11 layers from the water table to the bedrock surface. Because the cells are large relative to the small pumping rates at the extraction wells, flow directions near the wells would not be predicted with sufficient detail to determine whether or not the extraction wells would capture the plumes. However, the model is well suited for assessing the effects of the total pumping rates on regional groundwater levels, pond levels, and streamflows. The model was used to show the effect of pumping without re-injection of treated water, and pumping with the re-injection of the same volume of water downgradient of the extraction wells.

4.3 PLUME CONTAINMENT APPROACH

Plume containment will be accomplished by fences of extraction wells located immediately downgradient of the plumes. The water will be treated at a central treatment facility, then re-injected into the aquifer near the extraction wells. The purpose of re-injection at the toe of each plume is to minimize regional changes in water levels and streamflow caused by the extraction of the contaminated water.

The locations of the well fences and the number and pumping rates of the extraction wells in each fence are given in this plan to illustrate the concepts on which the plan is based. Many hydrologic and geologic factors, such as local variations in aquifer properties and complex flow patterns near the ponds and bogs, will have to be considered in the final design. The potential for recirculation (short-circuiting) of clean water between the extraction and injection wells will also have to be examined carefully. A greater separation may be needed between the extraction and injection wells than the 100-400 feet assumed in this plan to limit recirculation of water and insure complete capture of the plumes. The final design will also have to consider interferences among well fences, particularly where the plumes are in close proximity (e.g., SD-5 and the Western Aquifarm Plume).

The plan also only briefly considers other fates for the clean water. For example, the clean water could be reintroduced into the aquifer at a single location, or all or part of it could be distributed for water supply. The impacts of redistribution of this large quantity of water on regional water levels and directions of groundwater flow and contaminant migration would have to be evaluated.

This plan does not attempt to address these site-specific complications or all the options for reuse of the clean water. Rather, it is intended to be a simple, but realistic, conceptual model of the containment approach. This simple model can be used to evaluate the necessity, effectiveness, and cost of simultaneously containing the MMR's plumes.

4.3.1 Extraction Wells

Each extraction well will be a 4-inch or 6-inch polyvinyl chloride (PVC) cased and screened well completed within a subsurface 4-foot by 4-foot concrete vault. The vault will house the valves, flow meters, and electrical gear necessary for proper pump operation and control. The vault must be deep enough to allow the completed well head to be below the frost line. A sealed vault will be used to prevent rainwater and runoff from entering the vault. Similar well vaults are to be provided for the injection wells. This will be typical for all well vaults in the system. An intrinsically safe rated submersible pump will be installed in each extraction well. The well pump operation will be controlled using level switches installed inside the well, and primary control of all wells in the fence will be dependent on controllers monitoring the status of the treatment plant equipment. Mechanical flow totalizers and manual flow control valves will be installed at each well head.

The pumpage rate for the extraction wells was calculated based upon doubling the total volume of contaminated water in the plume moving toward the well fence in one day. The volume was doubled to account for edge effects of clean water entering the zone of capture around the edge of the plume. This volume was divided by 1,440 (number of minutes in a day) and subsequently divided by the number of proposed wells to determine pumpage rate in gallons per minute (gpm) per well. Actual well spacing and flow rates will be determined in the design phase of the containment approach.

All extraction wells will be developed and sampled with three rounds of samples per well, including USEPA 624 VOC, USEPA 625 SVOC, EDB, and Target Analyte Metals (TAL), USEPA 6010.

4.3.2 Injection Wells

Each of the injection wells will be placed within concrete vaults of the same design used for the extraction wells. No level controls or pumps will be located in the injection wells. Flow adjustments to maintain the proper volume to the injection manifold will be controlled by a single automatic flow control valve located on the main return manifold. Individual well flow control will be accomplished using manually operated control valves installed ahead of each well. Each well will also have a pressure gauge installed on the well casing inside the vault. Control of the flow will be based on the flow readings obtained from the extraction and injection flows. The rate of injection flow will be monitored and is not to exceed the rate of groundwater

extraction. Diversion of a portion of the cleaned water for use as golf course watering or irrigation will be provided as a method of regulating infiltration rates.

Two injection wells will be installed for each extraction well. The reasons for doubling the number of injection wells over the extraction wells are as follows:

1. The increased number of wells will allow better water distribution at the well fence.

2. The local mounding effects expected at the injection wells should be reduced.

3. The pressure required for re-injection should be diminished.

4. Re-injection wells tend to "plug" or "blind" across the screened interval more often than extraction wells.

5. Additional injection wells will allow the groundwater to be optimally balanced according to the pumping rates of the extraction wells nearest to each injection well.

6. A single injection well can be removed from service for a few hours for maintenance without significantly affecting the groundwater flow path. For this period of time, the injection rate for each well on either side of the well being serviced would be increased.

4.3.3 Monitoring Wells

Monitoring wells will be placed between the extraction and injection well fences at each plume. The wells will be 2-inch, PVC, surface completion wells with a steel cover for security. The wells will be placed approximately 400 feet apart at each plume. As a minimum, one well at each end of the plume and one in the center will be used to monitor the effectiveness of the well fences installed at the plumes.

An initial round of sampling will be done as each well is completed (Section 4.3.1), and then sampling will be conducted quarterly.

4.3.4 Horizontal Wells

Due to the volume of water that will be pumped to contain further migration of the plumes, a system of horizontal wells was considered. However, horizontal wells are not recommended for the following reasons:

1. The wells are very expensive.

2. They do not cover the vertical extent of the plume.

3. It is difficult to determine the radius of influence, or adjust the radius of influence if operations indicate the plume is not being contained.

4.3.5 Sandwich (FS-12) Plume Parameters

The FS-12 plume is contaminated with benzene and EDB at maximum levels of 1,600 and 597 ppb, respectively. The plume is approximately 5,000 feet long, 2,000 feet wide and 100 feet thick (HAZWRAP maps, 1994). The gradient for the groundwater in this area ranges from 0.00025 ft/ft to 0.0004 ft/ft. The average horizontal flow velocity is calculated to be 0.4 ft/d (HydroGeologic, 1992).

4.3.5.1 Well Fence Location and Details

The proposed location of the containment fence at FS-12 is shown in Figure 4.8. The location of the well fence was chosen based on its proximity to the leading edge of the plume, the groundwater contours, and the accessibility of the area for well installation. Since Camp Good News Road is almost directly along the leading edge of the plume and allows relatively easy access for drilling wells, it was chosen as the best area. Following the groundwater contours in this area still allows for the placement of all wells within 100 feet of Camp Good News Road. Fourteen extraction wells will be installed in a line parallel to the groundwater contours over 2,200 feet at a spacing of 160 feet between wells. An intrinsically safe rated submersible pump, capable of producing up to 35 gpm at 250 pounds per square inch (psi), will be installed in each extraction well.

A series of 28 injection wells will be located 100 feet downgradient and parallel to the extraction wells. The injection wells are to be positioned close to the extraction wells to avoid interfering with the State remediation project currently underway at the J. Braden Thompson Site. This site

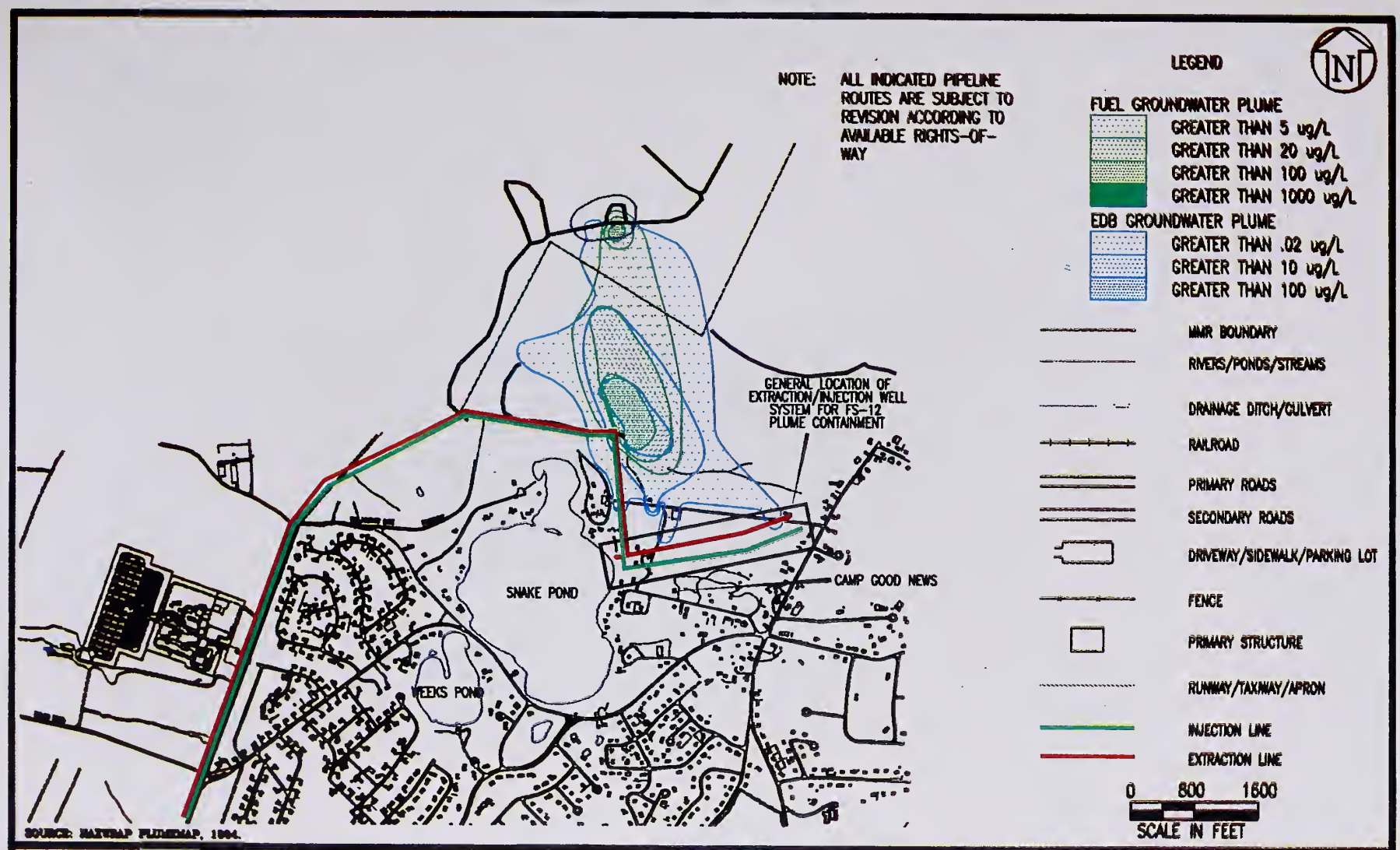

FIGURE 4.8

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FS-12 PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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is located approximately 250 feet south of the proposed injection well fence. A study will be required to determine if injection wells will interfere with cleanup efforts already underway at the J. Braden Thompson site. The final design may include additional extraction wells, if necessary, to assure the protection of Snake Pond and the continued viability of the Sandwich water supply well at Weeks Pond.

The total flow from the FS-12 area is expected to be 320 gpm to 350 gpm. The contaminated groundwater will be transported to a CTU through 8-inch diameter double-wall PVC or polyethylene pipe before being returned to the plume edge for re-injection. Interstitial leak detectors will be installed in the space between the two pipes. All pipe will be installed in 5-foot deep trenches and covered to maintain the piping below the frost line. After the groundwater has been treated by the equipment at the CTU, the treated water will be returned to the injection well manifold through 8-inch single-wall PVC or polyethylene pipe buried next to the extraction piping.

4.3.6 LF-1 Plume Parameters

The LF-1 plume is contaminated with DCE, TCE, PCE, CCL_4, vinyl chloride, DCA, TCA, 1,1,2,2-tetrachloroethane, and other fuel related hydrocarbons including BTEX and chlorobenzene. The plume is approximately 16,500 feet long, up to 6,000 feet wide, and up to 80 feet thick (HAZWRAP maps, 1994). The gradient for the groundwater in this area ranges from 0.0013 ft/ft to 0.0025 ft/ft. The average horizontal flow velocity is calculated to be 1.49 ft/d based upon a hydraulic conductivity of 280 ft/d (ABB-ES, March 1992).

4.3.6.1 Well Fence Location and Details

The proposed location of the containment fences at LF-1 is shown in Figure 4.9. The location of the well fences again were chosen based on their proximity to the leading edge of the plume, the groundwater contours, and the accessibility of the area for well installation. Highway 28 is located along the leading edge of the plume and allows relatively easy access for drilling wells. Wells may need to be repositioned slightly from optimum locations on the west side of Highway 28 due to residential area constraints. The east side of Highway 28 is unpopulated in the area of the proposed wells, but the terrain may require adjustments in the placement of the wells.

A total of 33 extraction wells will be installed in two areas ahead of the plume. Two rows of well fences will contain extraction wells spaced at 180-foot intervals for 2,800 feet across the northwestern end of the plume, and for 1,800 feet along the toe of the plume. The well fences will be parallel to the groundwater contours at the leading edge of plume LF-1. An intrinsically

FIGURE 4.9

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LF-1 PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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safe rated submersible pump, capable of producing up to 35 gpm at 250 psi, will be installed in each recovery well.

The total flow from the LF-1 area is expected to be 930 gpm to 1,000 gpm. The contaminated groundwater will be transported to the CTU through 12-inch double-wall PVC or polyethylene pipe before being returned to the plume edge for re-injection. Leak detection and trenching are identical to plume FS-12.

After the groundwater has been treated by the equipment at the CTU, the treated water will be returned through 12-inch single-wall pipe, buried adjacent to the extraction piping, to the injection well manifold. Injection well details are the same as plume FS-12, except that the two automatic flow control valves will be used to maintain control of the treated water that is being returned to the injection wells. A series of 66 injection wells will be located 300 to 400 feet downgradient and parallel to the extraction wells.

4.3.7 CS-10 Plume Parameters

The contaminants of concern and the maximum contaminant levels at plume CS-10 are as follows: DCE, 1,2-DCE, TCE, benzene, PCE, 1,1,1-TCA, methylene chloride, vinyl acetate, toluene, naphthalene, 2-methylnaphthalene, aluminum, antimony, arsenic, barium, beryllium, chromium, lead, manganese, nickel, and vanadium. The plume is approximately 12,500 feet long, up to 3,600 feet wide, and 40 to 80 feet thick (HAZWRAP maps, 1994). The gradient for the groundwater in this area ranges from 0.0015 ft/ft to 0.0019 ft/ft. The average horizontal flow velocity is 0.88 ft/d (CDM, November 1993).

4.3.7.1 Well Fence Location and Details

The proposed locations of the containment fences at CS-10 are shown in Figure 4.10. The location of the well fences were chosen based on their proximity to the leading edge of the plume, the groundwater contours, and the accessibility of the area for well installation. The proposed locations are on flat ground, on Base property, with easy access to drilling sites provided by the network of existing roads. However, by necessity, some wells may be located in areas that require clearing and grubbing.

The two well fences will contain a total of 43 extraction wells spaced at 160-foot intervals for 2,800 feet across the western lobe along plume CS-10 and at 160-foot intervals for 3,800 feet along the southern toe of the plume. The well fence will parallel the southern toe of the plume

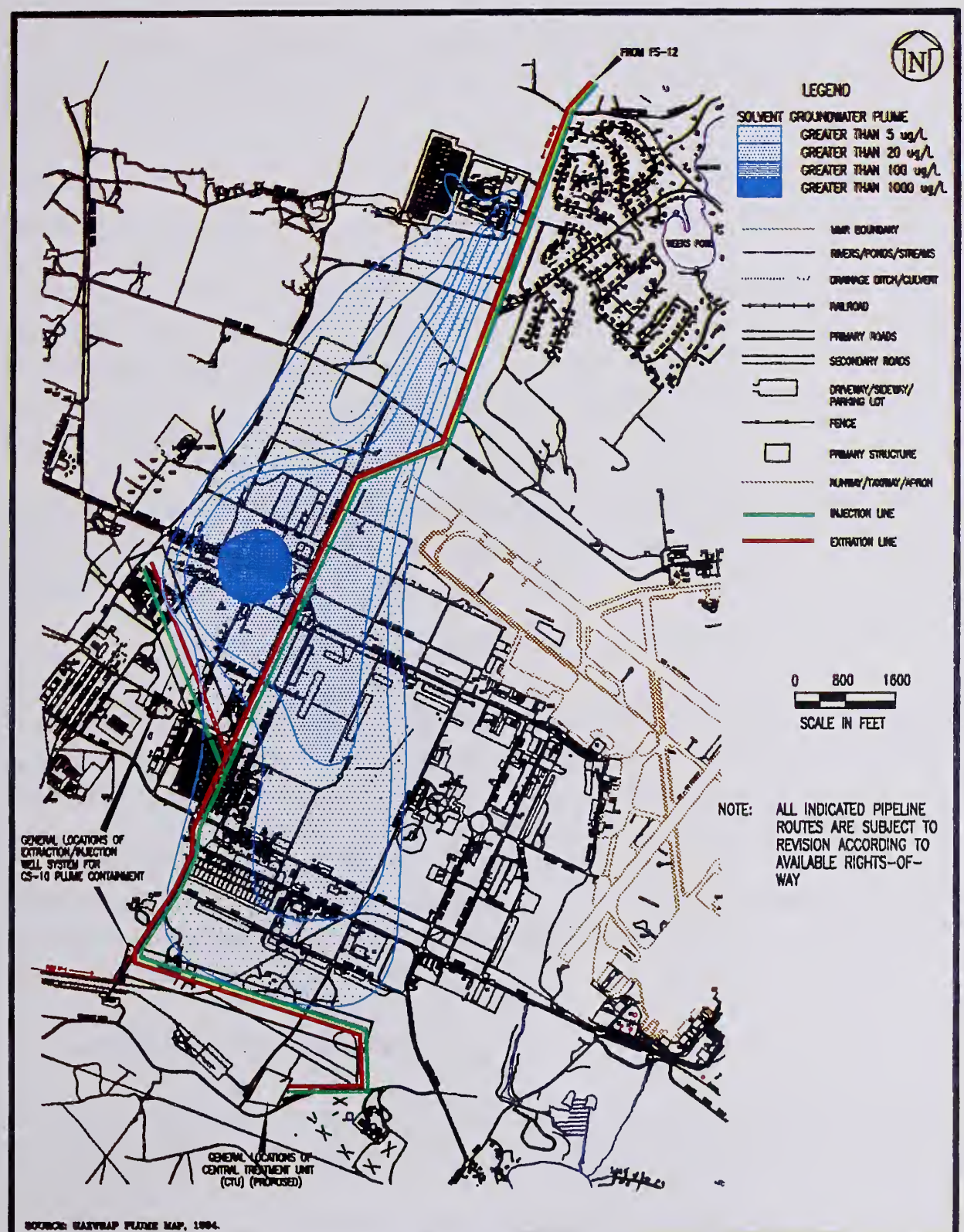

FIGURE 4.10

R:\MAYWAP\CS-10PLM

CS-10 PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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and also be parallel to the groundwater contours at the leading edge of plume CS-10. An intrinsically safe rated submersible pump will be installed in each extraction well, capable of producing up to 50 gpm at 250 psi.

A series of 86 injection wells will be located 300 to 400 feet downgradient and parallel to the extraction wells. The wells will be at the two locations shown in Figure 4.10.

The total flow from the CS-10 area is expected to be 1,200 gpm to 1,300 gpm. The contaminated groundwater will be transported to the CTU through 12-inch double-wall polyethylene pipe before being returned to the plume edge for re-injection. Piping in this area is expected to carry mixed plume flows and will be sized accordingly. The 12-inch size will be for flow prior to entering the main pipeline.

After the groundwater has been treated by the equipment at the CTU, the treated water will be returned to the injection well manifold through 12-inch single-wall pipe buried next to the extraction piping.

4.3.7.2 CS-10 High Concentration Area Treatment

The CS-10 plume conceptual system includes high concentration area treatment consisting of three extraction wells placed at the leading edge of the highest concentration area within the plume. The proposed location is near the intersection of Connery Avenue and Turpentine Road upgradient of the leading edge of the western lobe. These wells are proposed because of documented high concentrations and the need for additional information to refine plume definition at the leading edge of the western lobe. The containment system for the high concentration area and the western lobe of the CS-10 plume will be finalized in design following the collection of additional groundwater data.

4.3.8 Ashumet Valley Plume Parameters

The Ashumet Valley plume is contaminated with PCE, TCE, and DCE at maximum levels of 982, 95, and 1,200 ppb, respectively. The contaminant plume is approximately 18,750 feet long. As defined at the toe, the plume is more than 4,000 feet wide and is 70 to 80 feet thick (HAZWRAP maps, 1994). The plume is migrating approximately 40 feet below the water table.

The gradient for the groundwater in this area ranges from 0.0015 ft/ft to 0.0025 ft/ft. The average horizontal flow velocity is 2.7 ft/d (E.C. Jordan Co., 1991).

4.3.8.1 Well Fence Location and Details

It is proposed that a line of 28 extraction wells be installed at 150-foot intervals along Carriage Shop Road (Figure 4.11). This road lies near the leading edge of the Ashumet Valley Plume and runs perpendicular to the projected path of groundwater flow. The well fence would consist of extraction wells installed in or near the existing right-of-way for Carriage Shop Road. A gathering system will connect each extraction well with the main pipeline that is to be placed in the rights-of-way for Carriage Shop Road and Sandwich Road. The 28 extraction wells are to be completed using a 100 gpm intrinsically safe rated submersible pump and motor. The placement of wells and pipelines in existing rights-of-way would assure a nearby source of electrical power for the pumps and provide easy access to the system for service and maintenance under all weather conditions.

The total flow from the Ashumet Valley plume is expected to be 2,800 gpm. The contaminated groundwater will be pumped to the CTU through 24-inch, double-wall polyethylene pipe before being returned to the plume edge for re-injection. Leak detection and trenching is identical to that used at the other plumes.

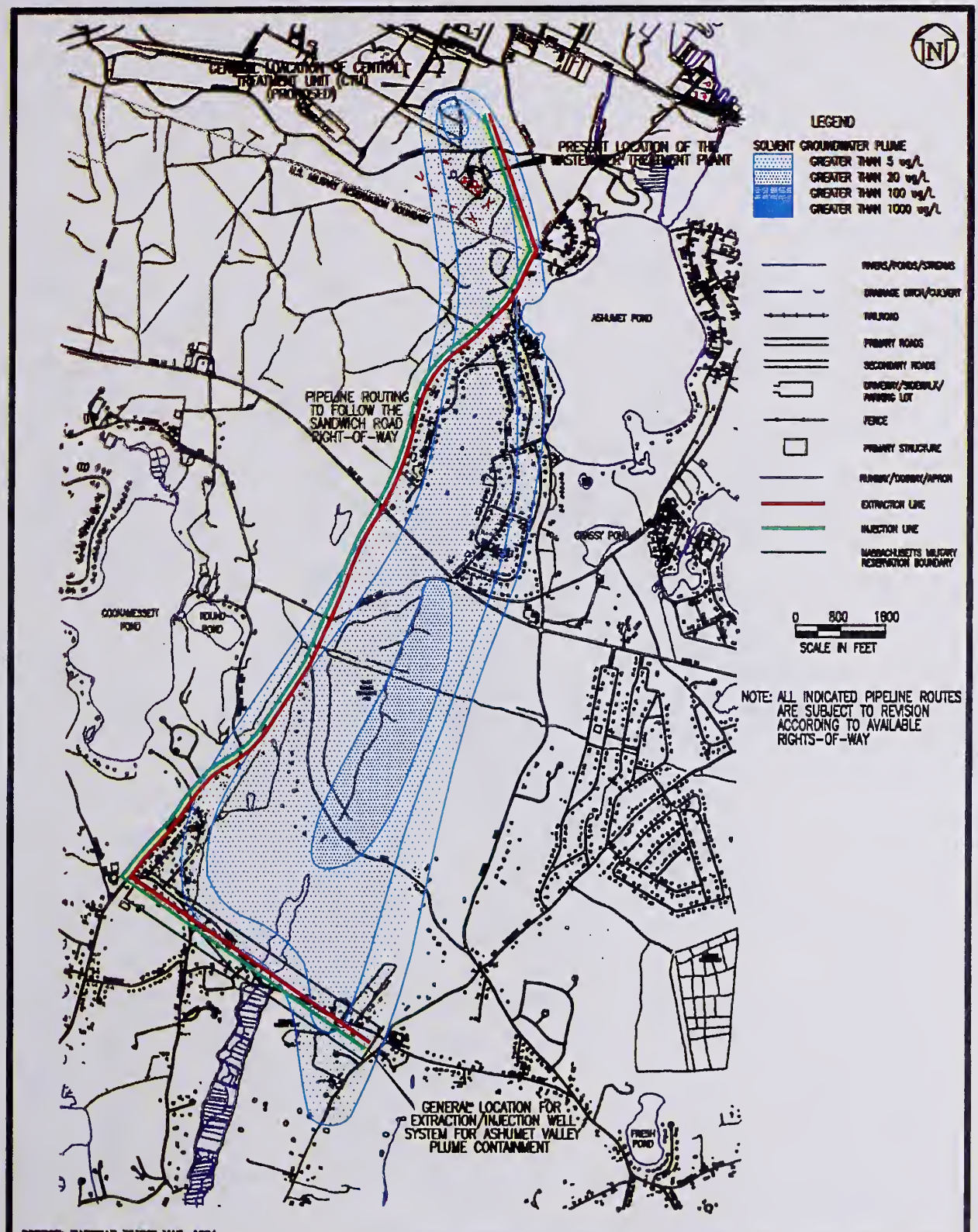
After the groundwater has been treated by the CTU, the treated water will be returned to the injection well manifold through 24-inch single-wall polyethylene pipe buried next to the extraction piping. Control valves will be used to adjust flow to the 56 plume injection wells.

4.3.9 SD-5 Plume Parameters

The SD-5 plume is contaminated with PCE and 1,2-DCE. The plume is approximately 10,000 feet long, 500 feet wide and 20 to 30 feet thick near the source and slowly broadens to a width of approximately 800 feet as it migrates southward with the flow of groundwater. At a point approximately 7,000 feet south of the source, the plume is influenced by the hydraulic gradient between Ashumet Pond and Johns Pond. At this point the plume takes an easterly course and expands to a width of approximately 1,750 feet as it flows toward Johns Pond (HAZWRAP maps, 1994). The gradient for the groundwater in this area ranges from 0.0018 ft/ft to 0.0021 ft/ft. An average horizontal flow velocity is calculated to be 4.4 ft/d (ABB-ES, 1992).

4.3.9.1 Well Fence Location and Details

It is anticipated that the containment fence will be located along the existing right-of-way for Hooppole Road. The proposed location for the containment fence is shown in Figure 4.12. The



SOURCE: HAZWRAP PLUME MAP, 1994.

FIGURE 4.11

ASHUMET VALLEY PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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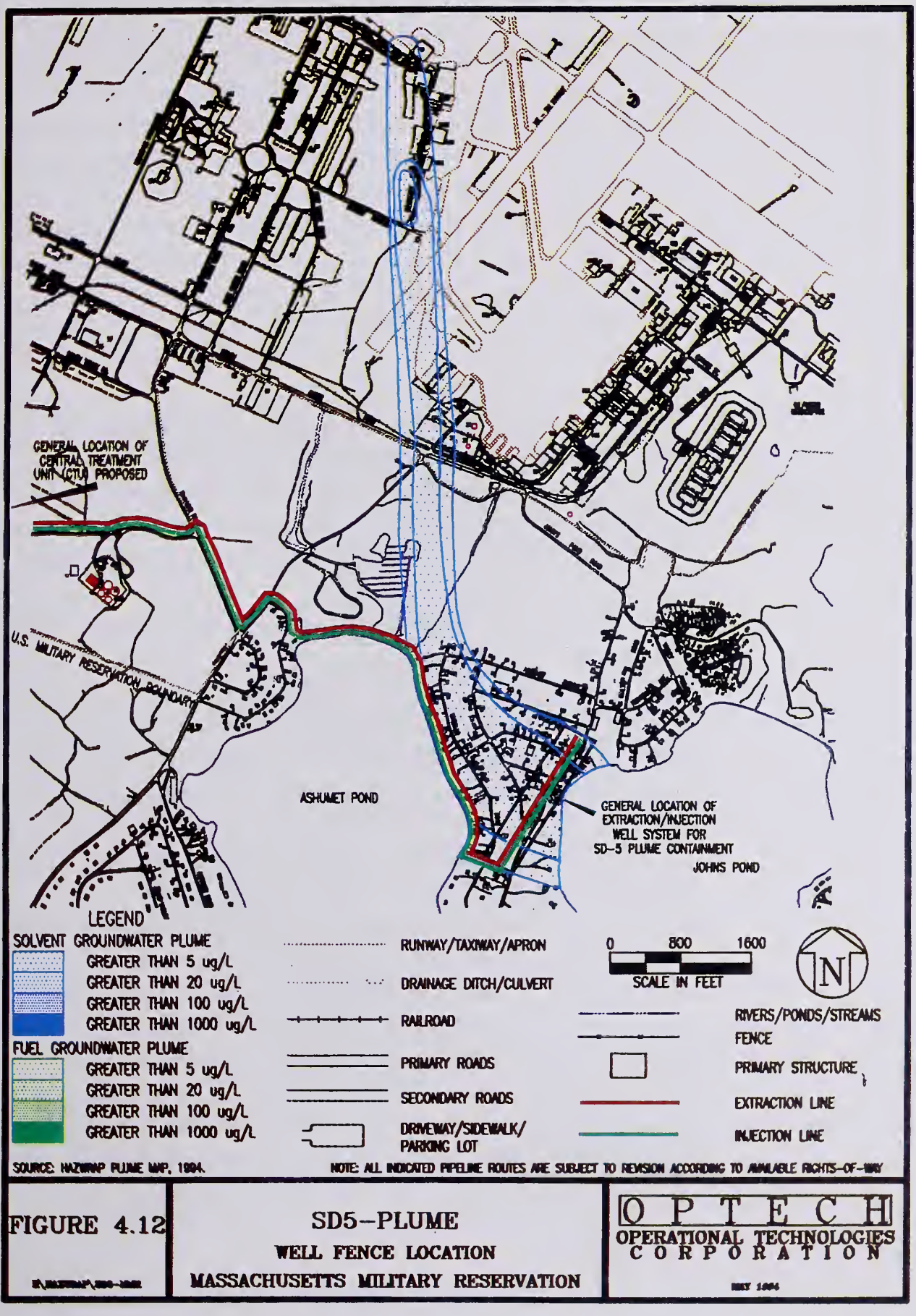

FIGURE 4.12

SD5-PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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well fence would consist of 15 extraction and 30 injection wells. Wells located along Hooppole Road would be perpendicular to the groundwater flow in this area, and the wells would be a distance of 200 feet to 500 feet from Johns Pond. Re-injection wells would be located along the edge of Johns Pond downgradient from the extraction well fence. Injection well sites and the associated right-of-way for a piping trench will have to be acquired in this area. Consideration was given to the direct discharge of clean water to the surface of Johns Pond, but it is believed that a surface discharge would migrate along the surface of Johns Pond and discharge to the Quashnet River. Re-injection of the clean water into the same horizon covered by the screened intervals of the extraction wells would have a mounding effect and would aid in plume containment.

Fifteen extraction wells, pumping 100 gpm each, are proposed for containment of the SD-5 plume. The wells are to be completed with 6-inch inside diameter (ID) well casing and screen. Injection wells, of which there will be 30, will be located as near to Johns Pond as possible and still allow all weather access to the well sites. (Well vaults, piping trenches, etc. are the same as those proposed for Ashumet.) Total flow from this area will be 1,500 gpm.

4.3.10 Eastern Briarwood Plume Parameters

Neither the contaminant sources nor the areal extent of the eastern Briarwood Plume have been determined. The plume containment system was designed according to the inferred shape of the solvent plume as shown on HAZWRAP Drawing No. E-HZ8885-H304, file name MMRH304.DGN dated 12 December 1993. This drawing lists PCE and benzene as the plume constituents. However, Task 2-5C for the IRP dated January 1993 lists TCE, 1,1,1-TCA, and 1,2-DCE, as well as the PCE listed above. Task 2-5C does not list benzene as a contaminant.

For the purposes of this report, the Eastern Briarwood Plume is calculated to be 1,200 feet wide and 20 feet thick at the leading edge. The HAZWRAP drawing shows the plume to be approximately 2,500 feet long, although a footnote on the drawing reveals that, of all the monitoring wells within the 5 ppb isoconcentration line that were tested, not all exceed 5 ppb total chlorinated solvents. Site-specific data for the Eastern Briarwood Plume has been reported to be insufficient (ABB-ES, January 1993). Based upon data for the southern MMR area, the gradient for groundwater is 0.0018 ft/ft; hydraulic conductivity is 380 ft/d, resulting in a groundwater flow velocity of 2.8 ft/d (ABB-ES, October 1992).

4.3.10.1 Well Fence Location and Details

The proposed location for the Eastern Briarwood containment fence is west of Moody Pond and just south of the MMR boundary. If further investigation determines that the plume has not migrated south of the MMR boundary as has been inferred, the well fence should be installed within the boundary of the MMR. Installation within the confines of MMR is preferred because there is no road and right-of-way to provide access to the containment wells and piping if installed outside the MMR. It is proposed that 8 extraction wells and 16 injection wells be installed to provide plume containment. The wells are to be completed using 4-inch ID casing and well screen.

The extraction wells are to be placed at 100-foot intervals in a line perpendicular to the migration of the groundwater plume. Each well will have a 40 gpm intrinsically safe rated submersible pump installed. Total flow will be 240 to 300 gpm. The injection wells are to be located at 50-foot intervals downgradient from the extraction wells.

The proposed location for the containment fence based on available information is shown in Figure 4.13. If the plume containment is located as proposed, approximately 9,000 feet of trench with 18,000 feet of pipe will be necessary, in addition to the lateral trenching and piping leading to each well location. Eight-inch double-wall polyethylene pipe will be used for transferring the water to the CTU. Single-wall 8-inch piping will be used for the injection piping. It is assumed that electrical power can be furnished from the MMR if the containment fence is located within the MMR boundaries or if sufficient power is not available from nearby residential areas.

4.3.11 Western Aquafarm Plume Parameters

The Western Aquafarm plume is contaminated with fuel related chemicals, primary toluene and xylenes. The plume is approximately 2,000 feet long and 800 feet wide (HAZWRAP maps, 1994). The groundwater gradient in this area is 0.002 ft/ft, and the horizontal flow velocity is 2.5 ft/d (ABB, Nov 1993).

4.3.11.1 Well Fence Location and Details

In-situ biotreatment of this plume was considered as a method to contain the plume, but the costs of providing a separate treatment system proved excessive. Therefore, the standard containment

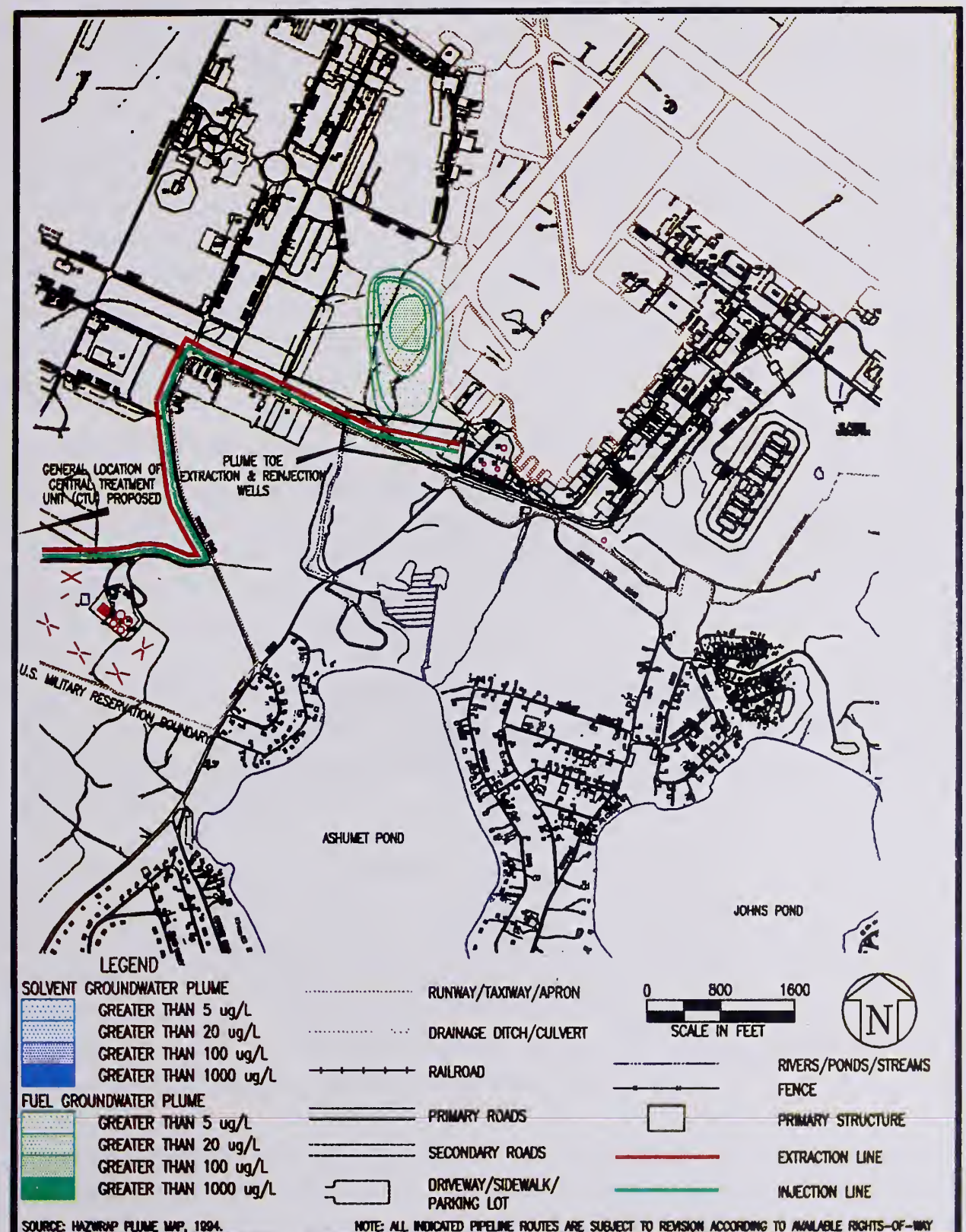

FIGURE 4.13

WEST AQUAFARM PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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approach used with the other plumes is recommended for use at the Western Aquafarm plume as well.

The proposed location for the Western Aquafarm groundwater containment fence is along South Outer Road (Figure 4.14). If the fence is located as shown, approximately 400 feet of trench and 600 feet of pipe will be necessary. Additional piping and trenching will be required for the lateral piping to the wells. Four hundred feet of 6-inch double-wall polyethylene pipe will be used for transferring the water to a CTU, and 200 feet of single-wall 6-inch pipe will be used for the injection piping. The piping and trenching will connect to the piping and trenching used for the Eastern Briarwood Plume.

It is proposed that nine extraction wells and 18 injection wells be installed to provide plume containment. The wells are to be completed using 4-inch ID casing and well screen. The extraction wells are to be placed at 100 foot intervals in a line perpendicular to the migration of the groundwater plume. Each well will have a 15 gpm intrinsically safe rated submersible pump installed. Total flow will be 130 gpm. The injection wells are to be located at 50-foot intervals downgradient from the extraction wells.

A minimum of three monitoring wells will be installed between the injection and extraction wells to monitor the effectiveness of the well fence in containing the plume. The monitoring wells will be 2-inch diameter and screened throughout the thickness of contamination. Construction details are outlined in Section 4.3.3.

4.3.12 Hydrologic Impacts of Containment

The plan proposes to pump almost 11 million gallons per day of water from the aquifer to contain the plumes. This volume is equivalent to the average daily recharge to 11 square miles of the Cape Cod aquifer. Because the aquifer on western Cape Cod is a single, interconnected system, the hydrologic impacts of this magnitude of water redistribution on groundwater and pond levels, and directions of contaminant migration could be significant.

A regional groundwater flow model developed by the USGS was used to obtain a preliminary assessment of these hydrologic impacts. The model is described in Section 4.2.4. Several scenarios of pumping and re-injection were simulated for comparison to the present conditions prior to implementation of the containment plan. Although there is inherent uncertainty in the model's predictions, they are an indication of the type and magnitude of the hydrologic impacts associated with the scenarios.

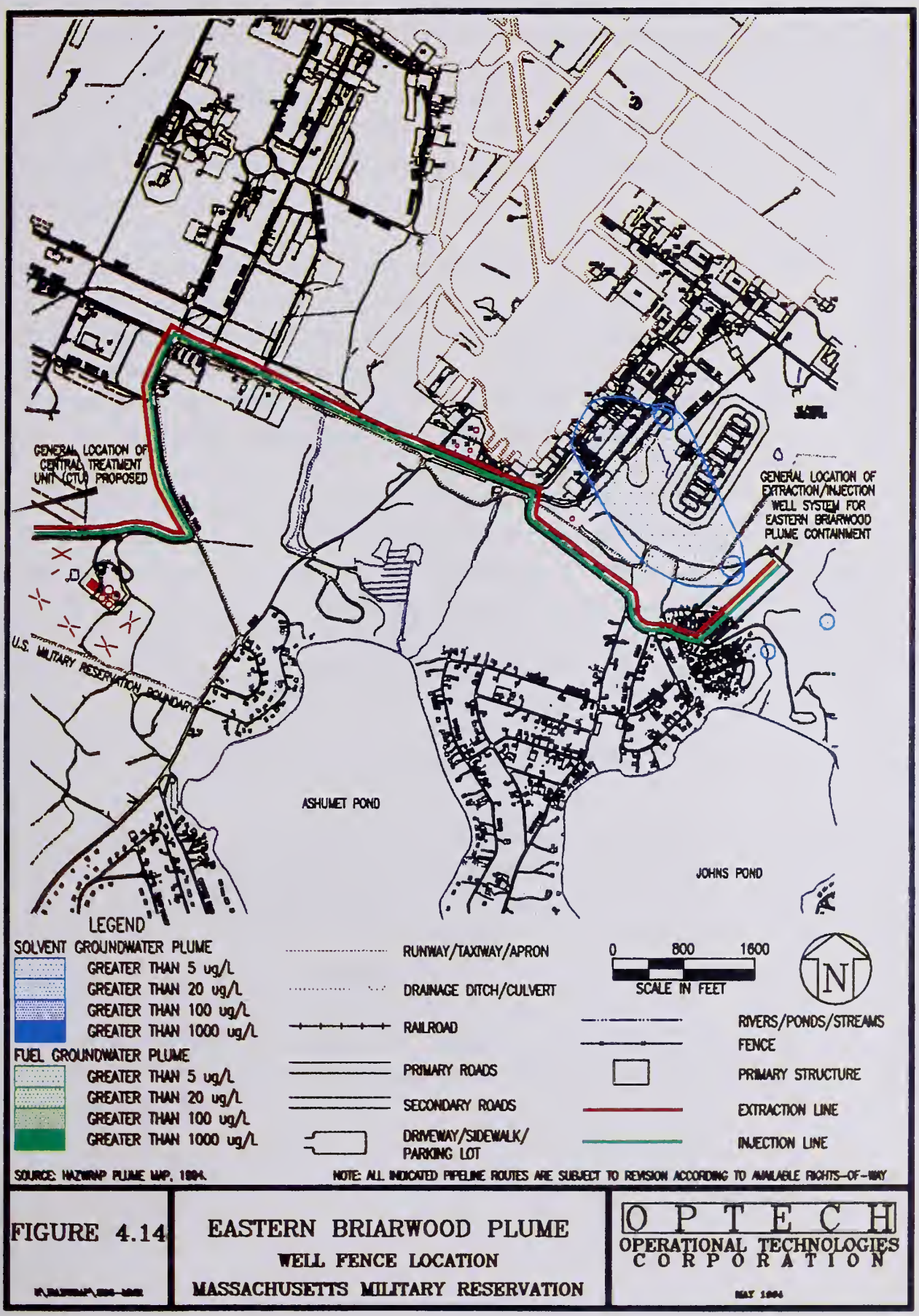

FIGURE 4.14

EASTERN BRIARWOOD PLUME
WELL FENCE LOCATION
MASSACHUSETTS MILITARY RESERVATION

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The plan proposes that groundwater extracted to contain the plumes be returned to the aquifer near the extraction wells. Simulation of this scenario indicated that the impacts on groundwater and pond levels and streamflows would be small because there would be no net withdrawal (pumping minus reinjection) of water from the aquifer at the well fences. Similarly, the regional directions of groundwater flow and, therefore, directions of contaminant movement would not change significantly.

The impacts on groundwater and pond levels and streamflows would be large, however, if the groundwater extracted to contain the plumes is not returned to the aquifer. Simulation of this scenario indicated that average groundwater and pond levels would be lowered by as much as 4 feet and average streamflows would decrease by as much as 40 percent. Regional directions of groundwater flow and thus plume paths might not change as dramatically, however, because the pumping is distributed along the southern side of the MMR.

Although other schemes could be used to return the clean water to the aquifer, they were not considered in this plan. The hydrologic impacts of these schemes would depend on the locations and rates of return of the clean water to the aquifer. For example, one option would be to re-inject all the water adjacent to the CTU. Even though this option would return all the water to the hydrologic system, the large redistribution of water would likely change directions of groundwater flow and affect the paths of the plumes, particularly those closest to the re-injection site.

4.4 GROUNDWATER COLLECTION AND TREATMENT

The objective of the proposed groundwater treatment system for the MMR is specifically to remove toxic organic and inorganic contaminants that may be present in groundwater. The product of this treatment system is an effluent that must meet drinking water quality standards which may be reintroduced to the aquifer or be used in the drinking water supply. The primary and secondary treatment options considered to meet these objectives are discussed in this section. Consideration is also given to the use of individual treatment units located at or near each plume, or a single central treatment unit for this application. Special concern should be given to the removal efficiency of these treatment options since the level of toxic organics contamination is in the ppb range.

4.4.1 Methodologies Considered

The systems considered for the primary and secondary treatment operations include air stripping, *in-situ* bioremediation, catalytic incineration, and carbon adsorption for removal of toxic organics, greensand filtration for removal of trace metals, and sludge de-watering and disposal operations for the removal of solid wastes generated as a part of the other processes.

4.4.1.1 Air Stripping

Air stripping is a primary treatment operation that is effective for the removal of toxic organics with a high volatility or low boiling point. Air stripping is a process involving the transfer of contaminants contained in one medium (water) into another medium (air) by bringing the two media into intimate contact. Various methods are employed to bring about this contact, including the injection of air into water through a series of small pores, bubble caps, or grids. Another method is to use a column which is packed with small tellurettes, saddles or open media and through which water and air pass counter currently. This greatly increases the surface area available for the exchange of contaminants from one medium to another. This process is further accelerated by recovering the vapor phase using a vacuum system. The aeration rate, bubble size/interface area, and aeration time necessary to remove the organics must be established by a pilot study. The vapors produced by this process must then be collected and treated by a separate secondary process; typically carbon adsorption, or catalytic incineration.

Aeration is a proven and relatively inexpensive approach to treating groundwater. A typical installation requires less space than carbon systems, and also requires fewer controls and related equipment. The technology is well established, and there are many manufacturers to choose from when selecting a unit. The removal efficiencies of air strippers remain fairly constant regardless of the concentrations of contaminants introduced into the unit. Many units also come pre-assembled and skid mounted which simplifies installation on a site.

Some drawbacks to using an air stripper are that the operation of the unit requires frequent and extensive maintenance in order to maintain optimal efficiency of the aeration or diffuser system. Without frequent cleaning, insoluble mineral carbonate deposits are formed at the diffuser pores or on the media surface and will greatly reduce the efficiency of the system. Also, the air blower may introduce ambient dust or organic matter into the bed or trays and cause fouling. This material must be removed to restore performance. This is accomplished with mechanical or chemical means. Mechanical methods are extremely labor intensive and use media blasting, peening, or scraping to remove coatings on the interior of the aerator. Chemical methods

generally require the use of an acid to dissolve the coating in the aerator. The acid must be neutralized and disposed of after it is drained from the system, which requires additional tanks, pumps, mixers and neutralization chemicals to accomplish.

Another problem with using chemical cleaning is that all wetted parts, including piping and pumps used with the aeration device, must be constructed from materials compatible with the acid used for cleaning. This can significantly increase the cost of a unit depending on the materials required.

Other problems associated with aeration include the fouling of the media, pores, etc. by biomass, or inorganic compounds (metals). This is a direct result of the increased oxygen content of the water passing through the stripper.

4.4.1.2 Carbon Adsorption

Carbon adsorption is an efficient treatment operation for the removal of organic compounds present in a gaseous or liquid matrix. Granular activated carbon (GAC) has a strong affinity for organic compounds that become preferentially adsorbed to the carbon skeleton. It also has a porous structure and provides a very large surface per unit volume of material. This allows for efficient transfer of contaminants from the water into the carbon skeleton.

When the GAC becomes "exhausted" (all adsorption sites occupied), it can be removed from the tank and be regenerated. Thermal (direct firing) or steam regeneration is used in most cases. The regeneration process removes the volatiles from the carbon matrix and allows the carbon to be reused. There is some loss in volume and efficiency associated with regeneration, and the gases generated during the regeneration process may still require further treatment prior to being released to the atmosphere.

An advantage of a carbon adsorption system is the filtering effect that a downflow carbon adsorber has. In addition to removing organics in the water, it also can filter minute particles from the water stream. Solids and particles that become entrained in the carbon can be removed by using a backwash pumping operation. The pH of the water is not changed during this adsorption process which also prevents fouling because of precipitation when the water from a carbon unit is re-injected into the groundwater.

Another advantage of carbon over air stripping is its ability to remove virtually 100 percent of the organics entering the unit. This can be accomplished with careful monitoring of a single adsorption bed or placing two units in series to prevent contaminant breakthrough.

Disadvantages to carbon adsorption include the initial cost of the system, disposal problems associated with the material backwashed from a carbon bed, and regeneration of the exhausted carbon.

Carbon systems are generally more expensive than other technologies such as air stripping, due to the size and number of adsorber units required for a given flow rate and the fact that the GAC media requires replacement and/or regeneration at regular intervals.

The backwashed material from a carbon adsorber must be settled and captured prior to being disposed of. This generally requires a large settling pond or additional equipment such as a filter press. Once the material is captured, it must then be disposed properly. This may be expensive depending on the composition of the material. Sampling is required prior to disposal.

Carbon regeneration is generally not done on-site, due to the size of the equipment required for regeneration. As carbon systems increase in size, on-site regeneration becomes a viable option. However, the proximity to homes and businesses must also be considered as part of the decision to place a regeneration system on-site. Transportation costs required to ship spent carbon to a regeneration furnace add more costs to the operation, and replacement of carbon lost during the regeneration cycle also adds to the cost.

4.4.1.3 *In-Situ* Bioremediation

Groundwater treatment using *in-situ* bioremediation typically involves installing a series of wells as a preliminary step to treatment. These wells are extraction and injection wells if groundwater is going to be removed and re-injected, or air injection and vent wells if air sparging is used. After installation of the wells, air, dissolved oxygen, nutrients, peroxide, and/or live cultures may then be introduced into the saturated contaminant zone to remediate the contamination. In the case of air sparging, air is forced into the aquifer to add oxygen to the water and increase the activity of the indigenous bacteria. Nutrients may also be added to the water prior to reinjection. As the water percolates through the aquifer, it carries the added oxygen, and/or nutrients to the indigenous microorganisms and spreads additional microorganisms throughout the plume, which in turn increases the subsurface microbial activity and enhances the removal of the contaminants.

Additional treatment is typically performed on contaminants which are captured in the saturated zone by the extraction wells and pumped to the surface. Treatment technologies used vary, but most common is aeration which adds oxygen to the water and assists in the removal of any volatile compounds. After treatment, the water is used for reinjection to the aquifer.

Advantages of bioremediation are that the remediation technology used (indigenous bacteria) is already acclimated to the contamination and using it for food. Rarely does a new strain need to be introduced to provide effective cleanup of the contamination. Chemicals used to enhance the growth of the bacteria are not harmful to surrounding life at the concentrations used, and are readily available and relatively inexpensive. Bioremediation also does not leave residues or byproducts that require further treatment. Furthermore, when the contaminant source is removed, the bacteria return to the previous population levels and do not grow uncontrolled.

Disadvantages to bioremediation include the reluctance of regulatory agencies to allow introduction of genetically engineered or non-indigenous bacteria to be introduced to the groundwater, the number of wells required to introduce nutrients and/or air into the groundwater, and the low growth rates of the bacteria caused by low water temperatures. This last item can be cured in some cases by heating the groundwater, but the costs are generally prohibitive, especially in colder climates. Overall, the cost of installing a bioremediation system at this location was found to be unacceptable.

4.4.1.4 Greensand Filtration

Manganese greensand filters are a treatment operation used to remove heavy metals and trace metals from solution in a liquid matrix. The manganese greensand filter acts as a catalytic surface for the binding of metals in solution to permit metals to become oxidized and consequently precipitate out of solution. The oxidizing agent present in the greensand filter is $KMnO_4$. The resulting precipitate can be removed from the filtration unit using a backwash pumping operation that empties into a clarifying tank and beltpress operation.

Greensand filtration operation is necessary for the removal of metals in solution that cause fouling of the carbon media in the secondary treatment operation. A major metal constituent found in the groundwater at MMR is iron at concentration levels between 2 parts per million (ppm) to 5 ppm (Task 2-5C, January 1993). This is the concentration level at which greensand filtration is most effective and can be used to extend the life of carbon which is fouled by iron at these concentrations. The optimal pH for this operation is close to neutral (between 7.0 to 7.5). The pH of the groundwater at MMR (Task 2-5C, January 1993) is approximately 6.6 and

may need to be adjusted in order to increase the efficiency of the removal operation. The expected life of a manganese greensand filter is 10 years provided its operation is maintained within the neutral pH range of 7.0 to 7.5.

Advantages to greensand filtration are its effectiveness in removing iron from solution at the levels found at MMR, the small area required for placement of equipment, and the fact that the technology is proven and reliable. Many suppliers offer packaged systems that can be installed with a minimum amount of additional site work.

Disadvantages to using greensand filtration include the generation of a disposal product through backwashing, chemicals required for media treatment, and additional pumps and tanks required for backwashing operations.

4.4.1.5 Catalytic Incineration

Catalytic incineration is a process in which VOC laden air is passed through a catalyst at elevated temperatures to oxidize the contaminants. The catalyst is used to lower the activation energy required to carry out the oxidation reaction. This allows a lower temperature to be used for the oxidation of the VOCs being treated and requires less fuel than a thermal incineration unit given the same concentration. The temperature required for catalytic oxidation is always lower than that required for thermal oxidation.

An advantage of catalytic oxidation is that at elevated contaminant levels, it requires little supplemental fuel for operation and the reaction is sustained with just the contaminants in the air stream. It is also a proven and reliable (with proper maintenance) operation.

Disadvantages include the high initial cost, high level of maintenance required to prevent "poisoning" the catalyst, the requirement of a supplemental fuel source at low VOC concentrations, and that the technology is primarily a gas phase only treatment approach. Liquid wastes applications are limited, and catalytic incineration is not used for solid waste disposal primarily due to fouling and catalyst poisoning.

4.4.1.6 Sludge De-watering and Disposal

The operation of both manganese greensand filters and carbon media will produce a backwash effluent that contains solids that must be contained and disposed. The level of solids present in the backwash is expected to be 5 percent for the greensand filtration and 1 percent for the carbon

media. This corresponds to a total of 500 to 700 pounds per day (lbs/day) of captured material (based on a flow rate of ten million gallons per day, and a 5 ppm concentration of metals in the incoming water). The greensand filters will be backwashed in cycles to produce approximately 1,500 gpm for each treatment unit. The carbon media will be backwashed in cycles to produce approximately 1,200 gpm total per unit. The backwash from the greensand filters can be adequately treated by a plate and frame or filter press unit operation that will de-water the sludge to produce a cake of solids that may be landfill disposed and a filtrate that may be reintroduced to the treatment system. The backwash from the carbon adsorption unit process will need to be settled in a large clarifying tank to separate the solids from the supernatant. The sludge from this operation can then be de-watered at a filter press operation and the supernatant and filtrate may be recycled through the treatment system as a primary influent.

The use of a drying bed for de-watering sludge has been considered for this application and may be used in lieu of a filter press operation. This option is limited by the availability of space to accommodate this operation.

The final solid waste product of this operation will be landfill disposed following the necessary regulations for proper disposal. The solid waste will be analyzed to determine if it has a toxicity characteristic, as defined in Resource Conservation and Recovery Act (RCRA) hazardous waste regulations. Any applicable permits, manifest forms or land disposal restriction notifications will be documented and recorded in compliance with RCRA regulations.

4.4.1.7 Regeneration of Carbon Adsorption Media

The regeneration of carbon adsorption media to remove the organics and inorganics that have saturated the carbon may be achieved on the installation. Carbon media can be reactivated by using either a kiln furnace incinerator or a steam autoclave unit. The use of this type of process unit operation must be permitted by the Clean Air Act regulations and demonstrate total enclosure and containment of volatile contaminants and pollutants. The cost for purchasing this system, and maintenance costs for its operation may be prohibitively expensive.

4.4.2 Individual Treatment Unit (ITU) Approach

The concept of installing individual ITUs on each of the plume sites has been evaluated. The ITU approach provides each containment fence a customized groundwater treatment unit that is sized and designed only for that particular application including a structure to house the unit operations. This approach will require more people to operate the individual units. The

distances between the units is such that it is impractical to assume that two people per shift can adequately maintain seven individual units. At least four people per shift are expected to be required to maintain seven units effectively.

Utility costs are expected to be more than that required for a CTU due mainly to the additional number of pumps required, lighting and duplication of control systems required for proper operation of each ITU.

For off-base installations, the ITU installation would need to be acceptable to the adjacent neighborhoods. Land would also have to be purchased or condemned to allow the siting of an ITU. Therefore, to avoid conflicts with residents in the thickly populated areas of the Ashumet Valley Plume, Eastern Briarwood plume and FS-12 plume, on-base installation is the only acceptable alternative for these ITUs. The ITU drawing and location shown in Figures 4.15 and 4.16 are representations of the possible ITU installations.

4.4.3 Central Treatment Unit (CTU) Approach

The concept of treating the groundwater of all seven plume fences in one CTU has also been evaluated. The CTU approach (Figure 4.17) provides a groundwater collection and piping system from the point of extraction to the point of reinjection. The contaminated groundwater will be piped to the CTU in a double wall or double containment PVC or polypropylene piping. The CTU will be housed in a structure or adjoining structures at one proposed site which is central to the seven plume sites.

This approach eliminates the problems associated with siting a treatment unit off-base and has the benefit of economies of scale associated with it. A significant savings would be realized during the long-term operation of this unit because of reduced utility costs and manpower requirements. Less lighting is required, and fewer pumps and controls are needed. Manpower requirements are expected to be two people per shift. Also, fewer buildings, and grounds improvements are needed.

4.5 RECOMMENDED TREATMENT SYSTEM

The recommended treatment unit for the conceptual plan is a CTU. A centrally located treatment system approach was based on financial, performance related, and public acceptance criteria. The CTU approach is the most acceptable concept for the treatment system because it reduces the capital costs for equipment and installations, has greater public acceptance due to

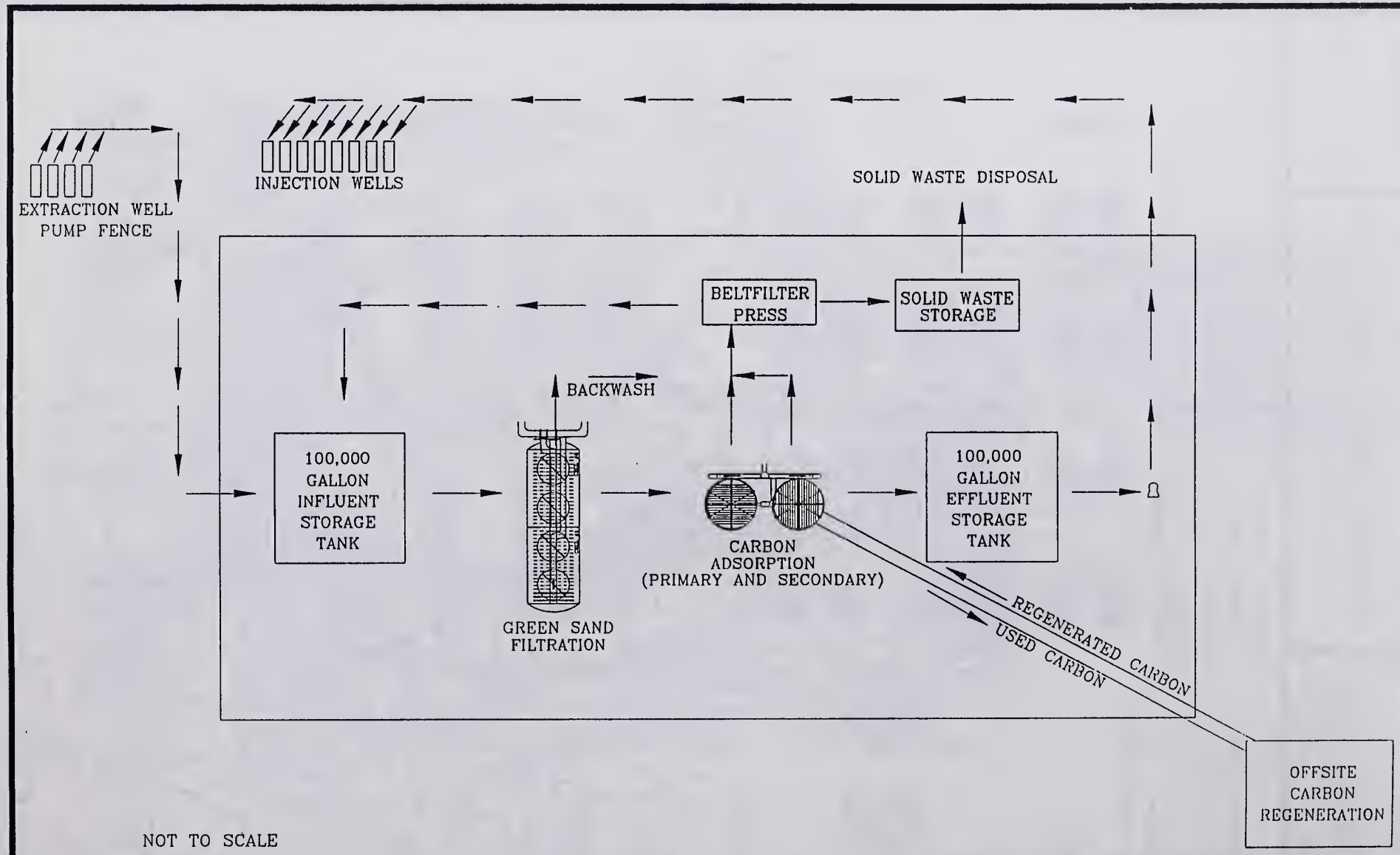

FIGURE 4.15

R\OTIS\ITU

INDIVIDUAL TREATMENT UNIT
MASSACHUSETTS MILITARY RESERVATION

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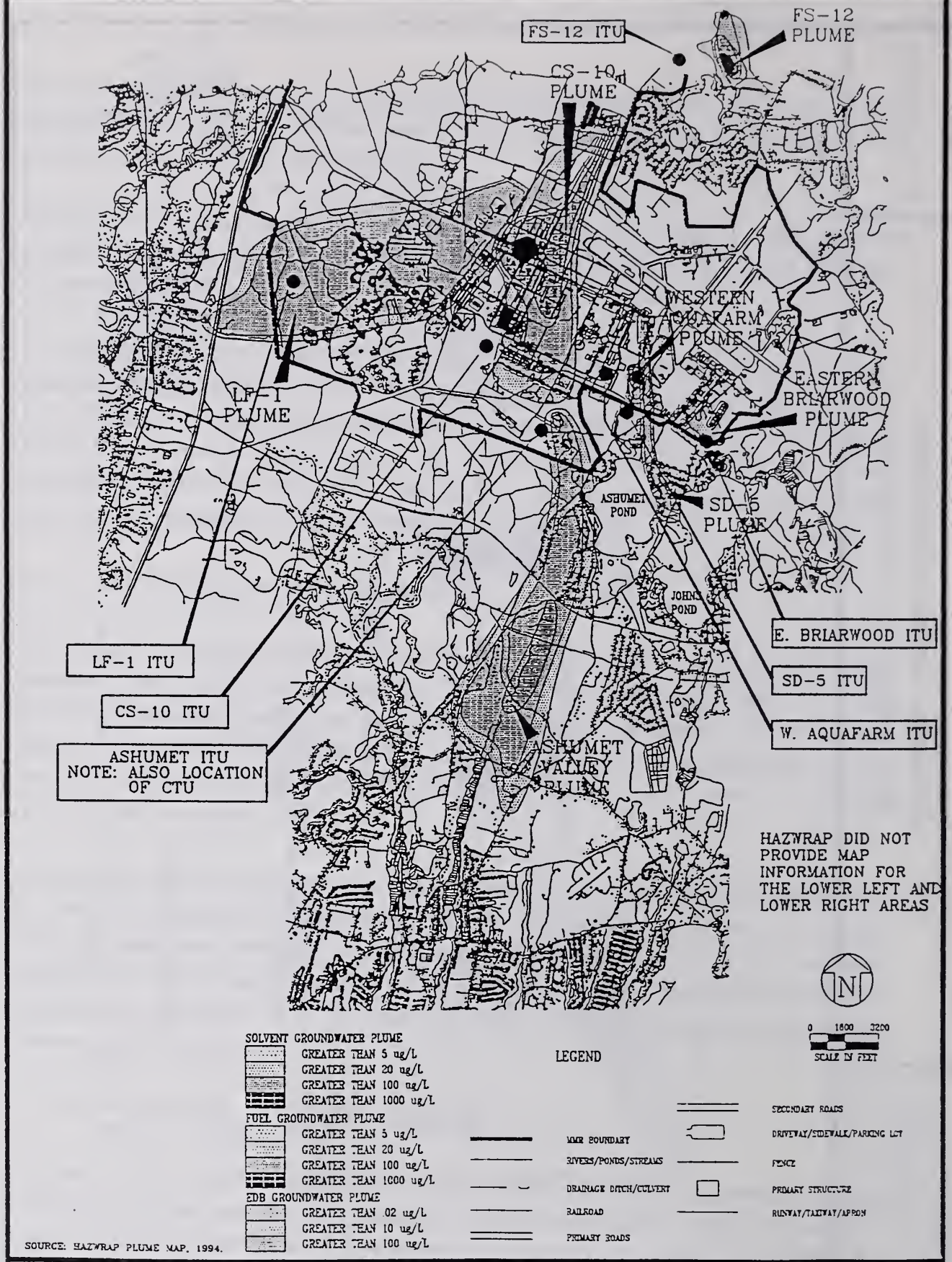

FIGURE 4.16

ITU/CTU LOCATION MAP

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R:\HAZWRAP\OTIS-MAP

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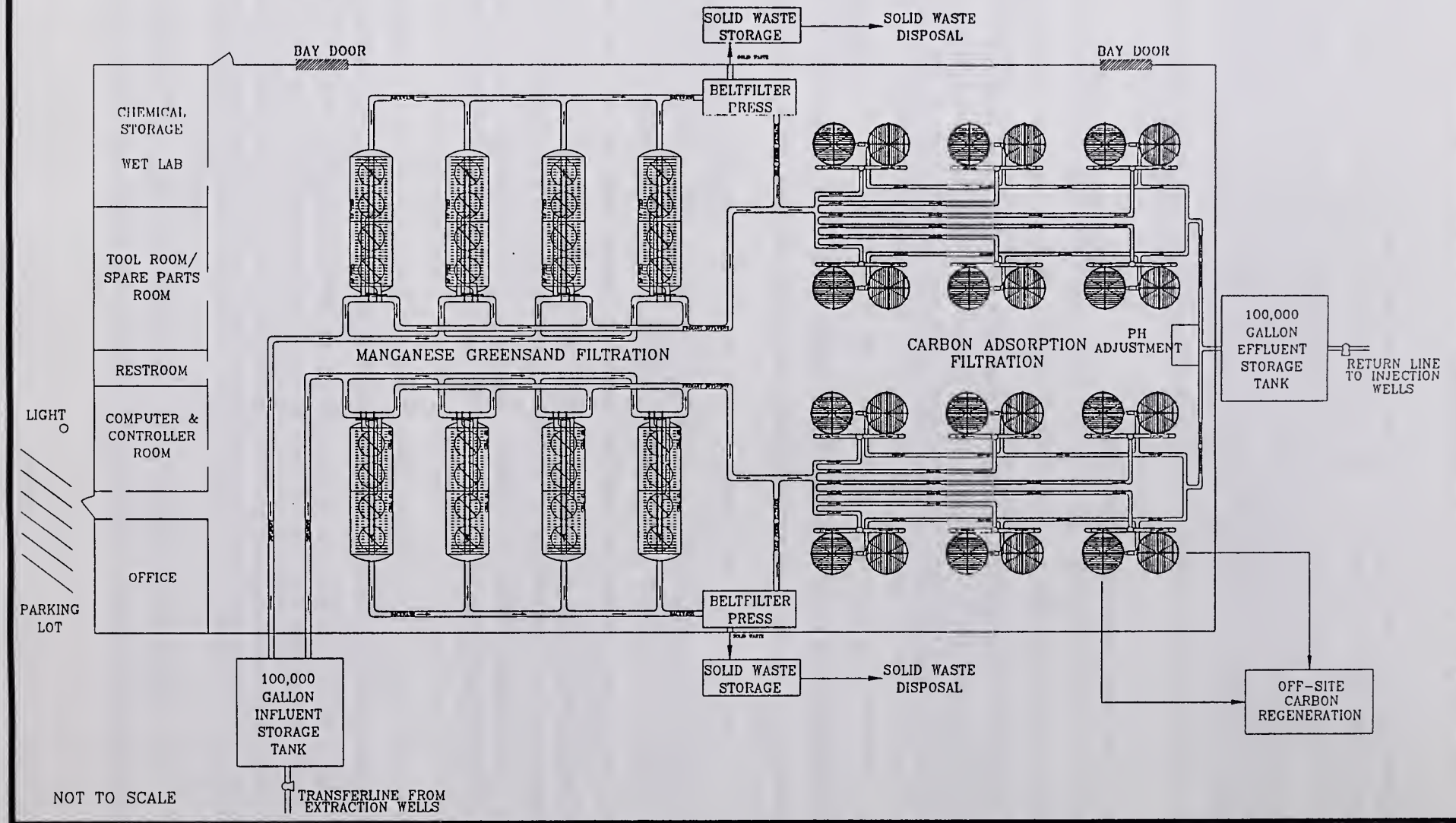

FIGURE 4.17

R\OTIS\CTU

CENTRAL TREATMENT UNIT

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its location away from housing areas, requires less manpower, and fewer building and grounds improvements.

Greensand filtration was selected to remove metals (primarily iron) from the water prior to the primary treatment unit. Greensand filtration requires a much smaller treatment area than settling tanks, and is suited for continuous flow. Settling tanks require large areas of land, and are batch systems which are unsuited for continuous flow processes. They typically require large amounts of chemical flocculents to be added which add to the sludge volume and cause increased disposal problems.

Carbon adsorption technology was chosen for use at the CTU instead of air stripping primarily because of the ability of the carbon to remove essentially all organic contaminants. Another reason for selecting adsorption technology is because of the reduced maintenance associated with carbon versus air stripping. Also, carbon or thermal treatment is still required if an air stripper is used since the air stream leaving the air stripper must be treated. The amount of carbon required for treatment of the air leaving the air stripper is only 1 percent to 4 percent less than that required if carbon alone is used. For that reason alone, air stripping was considered to be a less attractive alternative.

On-site carbon regeneration was not selected primarily because the capital costs of a regeneration unit are not expected to be cost effective when compared to off-site regeneration by the manufacturer.

Duplicate pumps and other vital components were chosen to maintain continuous operation even during required maintenance of the primary pieces. The added cost of duplicate systems will prevent continued plume migration because of a maintenance related failure of a system within the plant.

4.5.1 Central Treatment Unit

4.5.1.1 General Description

The proposed CTU is sized to treat up to 8,000 gpm of groundwater contaminated with VOCs, semivolatile organic compounds (SVOCs), chlorinated solvents, and metals. Table 4.2 lists the seven plumes that will be contained and the expected flowrate from each of them.

Table 4.2
Massachusetts Military Reservation Plume/Flow Rate List

Plume	Flow Rate (gpm)
FS-12	350
LF-1	1,000
CS-10	1,300
Ashumet Valley	2,800
SD-5	1,500
Eastern Briarwood	300
Western Aquafarm	130
Total	**7,380**

gpm – gallons per minute.

The proposed location of the CTU is on the southeast corner of the MMR near the current sewage treatment plant. This location was chosen because it is centrally located with respect to all of the plumes, and the area already has roads and utilities at the site, which will reduce construction costs.

The general description of the overall plume containment system is shown in Figure 4.18, MMR Conceptual Flow Schematic. As shown in the schematic, water is extracted from the plume areas and pumped to the CTU. All groundwater is discharged into a collection tank prior to being pumped to the filtration units. Combining flows into a single collection tank will allow a steady flow to be maintained to the filtration units, maximizing their efficiency. The greensand filtration units are designed to remove metal contamination and suspended solids entering with the water stream. After passing through the filter beds, the water is passed through carbon adsorption beds. The proposed carbon treatment units are placed in series to provide contaminant breakthrough protection.

Backwash cycles are incorporated into the filter and carbon units. The backwash makeup water is treated water taken from the treated water storage tank. It is pumped back through the carbon beds and filter beds, and discharged along with any loosened solids into the backwash collection tank. After settling, the contents of the backwash collection tank are pumped into a filter press to remove solids from the water. After drying, the press solids are removed, sampled, and disposed in the appropriate manner. The water stream exiting the press is returned to the groundwater collection tank for further treatment. After the water has passed through the carbon

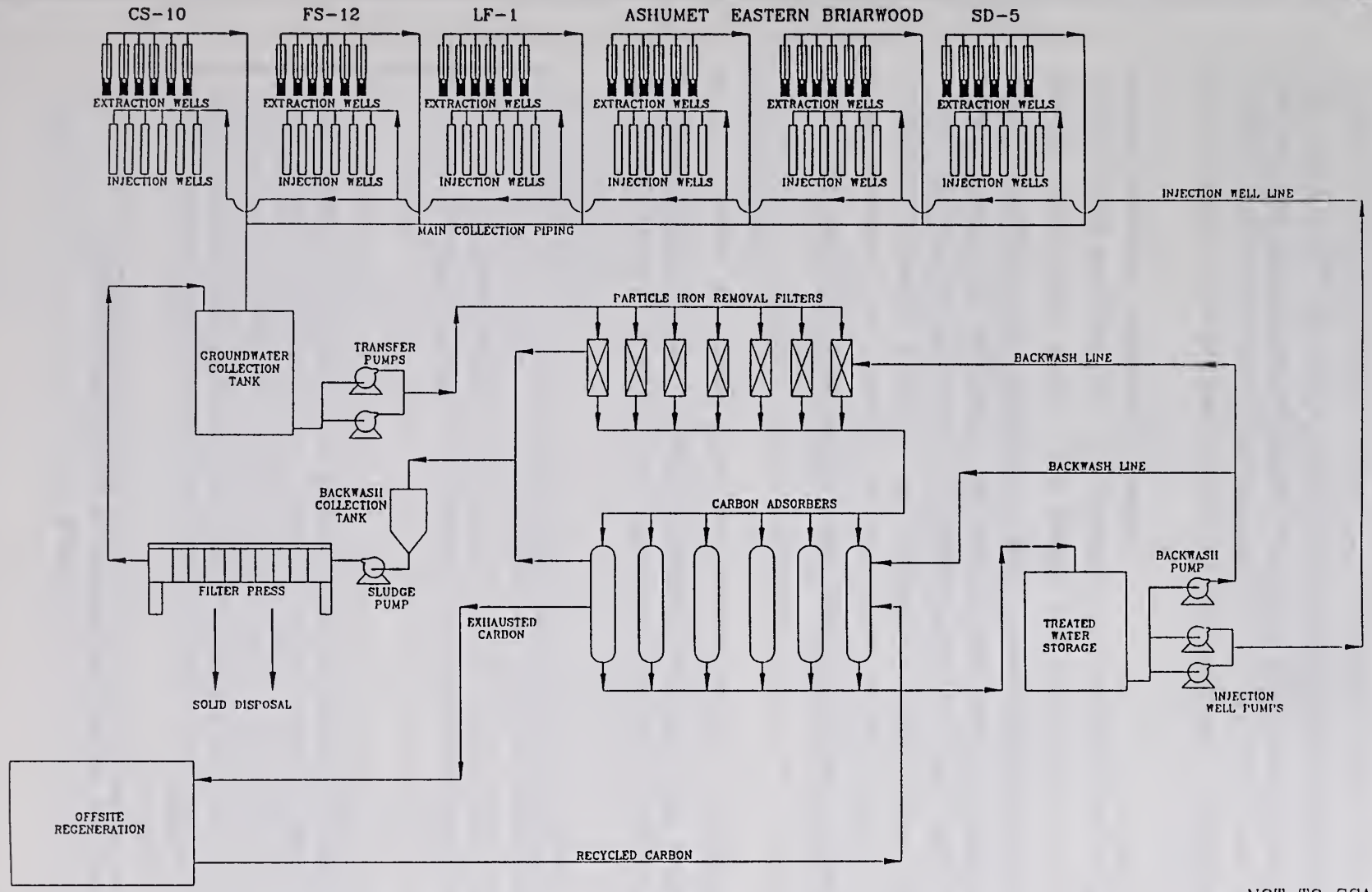

FIGURE 4.18

R\OTIS\SCHEM

CONCEPTUAL MODEL FLOW SCHEMATIC

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adsorbers, it is pumped to the treated water storage tank for distribution. Eight pumping assemblies consisting of dual pumps, valves, gauges, controllers and piping will distribute the cleaned water to the various injection well fences, the backwash system for the filters and adsorbers, and area ponds or Base water supply as needed. Since the each plume will require different rates of return flow, and return flows to ponds and the Base water supply will be intermittent, each of the different pump assemblies is necessary for accurate control of these return flows.

The flows, pipeline pressures, levels and various other functions of the CTU, and accompanying wells will be monitored and controlled by a central control system located at the CTU Site. The entire system will be capable of automatic control with allowances for manual overrides.

The CTU will be located on a curbed concrete slab designed to contain spills and overflows. Centrally located sump(s) will pump accumulated water into the groundwater collection tank as required. Supplies, control systems and weather sensitive equipment will be housed inside covered enclosure(s) as needed.

Manpower requirements are 7 days a week, 24 hours a day coverage to monitor and maintain the system. A minimum of nine (eight non-exempt and one exempt) employees will be required for proper operation of the plant. This number of employees will insure a minimum two-person coverage at all times while the plant is operating.

Electrical requirements at this location will require an electric substation set up on the site to handle the amount of power required by the CTU. Transformers will be installed at the site for the various power requirements of the CTU.

4.5.1.2 Groundwater Collection Tank

The groundwater collection tank will be sized for a volume of 100,000 gallons. This will allow a minimum of 12 to 13 minutes residence time at full flow from the surrounding wells. This will be sufficient time for the operation of the level controls to prevent overflow, and allow pH adjustment (if used) of the water entering the greensand filters. The tank will be steel open top construction with insulated walls. The collection tank will have a concrete dike around it to contain the full volume of the tank should a failure occur. Two 8,000-gpm capacity centrifugal pumps will pump water from the tank to the greensand filters. The pumps will be capable of running independently of each other and will be alternated to maintain even wear and reduce individual maintenance costs. The non-operating pump will be in a standby mode and act as a

backup in the event of a failure of the other pump. All aboveground lines associated with the tank and pumps will be insulated and electrically heat traced to provide freeze protection. Pumps and piping located in heated buildings will not require freeze protection measures. The tank level will be maintained at a predetermined level using level controllers connected to a central system.

4.5.1.3 Metal Removal/Sediment Removal Filters

The filtration system proposed for this system is a series of automatically backwashing greensand filters. The filters are designed to remove primarily iron contamination from the water, but will also remove other metals as well. Sediments will also be trapped on the surface of the beds. The purpose of these filters is to prevent fouling of the carbon absorbers. The filters will be arranged in parallel to reduce the individual loading on each unit. The filters will be rated at 900 gpm each, and a total of 12 units will be installed. This will allow one unit to be backwashing, one unit to be regenerating, and one unit to be idle while nine are in operation at any one time. The filters will be in closed horizontal steel tanks 36 feet long and having a 12-foot outside diameter. The units will have automatic backwash cycles based on pressure drops across each filter bed. The media will be manganese greensand between anthracite and gravel, filling each filter to a depth of 41 inches. The freeboard will be sufficient to allow bed expansion necessary for cleaning. The filter units will be located in a heated enclosure to prevent weather-related problems. Regeneration chemicals will be stored in the area near the filters. The filters will require periodic regeneration with potassium permanganate ($KMnO_4$). A central system of tanks and pumps will supply $KMnO_4$ to each filter unit.

4.5.1.4 Carbon Adsorption Units

The carbon adsorption units proposed for this system are a series of automatic backwashing coal based carbon adsorption units. The units will be placed in parallel to reduce the loading to each unit, and each unit will also be in series with another unit to prevent breakthrough of the contaminants. These units are designed to remove VOCs, SVOCs, and chlorinated solvents from the water stream. Each bank of two units will be sized to treat 700 gpm. The carbon adsorption system proposed for this application involves the use of 15 banks, each composed of two steel vessels containing 20,000 pounds of carbon each; these are plumbed in series as a primary and secondary unit. Each unit will be able to process 700 gpm at full capacity, at 15 minutes of residence time. The primary tank serves as the treatment unit, while the secondary tank serves as a polishing tank or as a backup treatment unit if the primary unit becomes saturated and allows a breakthrough of organics with the effluent. The carbon saturation or

fouling rate is approximately 150 lbs/day at the expected loading rate. Analytical testing of the primary and secondary effluent for the presence of total toxic organics will be required in order to establish the actual status of the treatment efficiency. The presence of toxic organics in the primary effluent will also indicate the need for the carbon to be removed and replaced with new carbon. Additionally the secondary tank can be replumbed to become the primary tank by repositioning a valve, thus allowing the tank with fresh carbon to become the secondary tank, in a first-in, first-out fashion.

A total of 15 units are installed to allow two units to be backwashing, and one unit to be idle while 12 are in operation. Each unit will contain 20,000 lbs of carbon. The horizontal tanks will be closed top steel units, 22 feet tall, 23-1/2 feet long and 7-1/2 feet wide. Flow rates will be limited to 700 gpm throughout the bed, with a residence time of 15 minutes. The units will automatically backwash when the pressure drop across the bed increases beyond the set point. Each tank will be designed with the proper amount of freeboard to allow full bed expansion during backwashing. It is expected that the life of each unit will be three to four months before regeneration is required. Carbon will be exchanged as required by the manufacturer or his representative. The carbon units will be housed in a heated enclosure next to the filter units. Additional freeze protection measures are not expected to be needed for these units.

The carbon adsorbers will have flow, level and pressure indicators/controllers to control the operation of the entire CTU. Alarms will be included for various modes.

4.5.1.5 Backwash Collection System

The backwash effluent coming from the carbon adsorbers and greensand filter units will be collected and filtered prior to being returned to the groundwater collection tank. A 30,000-gallon tank will be used to collect the backwash effluent. The tank will have enough capacity to hold simultaneous backwash flows from a bank of filters and carbon adsorbers at the same time.

At a predetermined level, the contents of the tank will be pumped through a plate and frame filter press. Two 300-gpm (at 90 psi) centrifugal pumps (sized to provide sufficient time to drain the backwash tank before the next backwash cycle is required) will pump the contents of the backwash tank into the press. Each pump will operate independently. The pumps will be alternated to reduce wear and maintenance. In the event of a pump failure, the alternate pump will be placed in service as needed.

The press will capture the solids washed off of the beds of the filter and carbon units. When the press has been filled, compressed air will be introduced to the press to dry the cake prior to removal and disposal. After drying the cake, it will be removed from the press, sampled and disposed of in the appropriate manner.

The filter press will operate automatically during the fill cycle, and have status and pressure indicators which will provide control inputs to the main control system. The tank, pumps, and filter press will be housed in a heated enclosure and will not require freeze protection. The return line to the groundwater collection tank located outdoors will require insulation and heat trace to protect from freezing.

4.5.1.6 Effluent Collection Tank Operation

After passing through the carbon adsorbers, the treated effluent will discharge into the collection tank. From here it will be redistributed back to the various plumes and re-injected into the ground. Distribution to the Base water supply or ponds will be provided as required. Each plume will have a pair of dedicated centrifugal pumps sized at the same flowrate as the total extraction flow from that plume. The pumps will be alternated and operate independently of each other. A bypass line from each plume manifold will return excess flow to the collection tank. Level indicators/controllers, flow indicators/controllers and electric control valves will be included as part of the system. A backwash manifold consisting of two centrifugal pumps, piping, controls, and valves will also be connected to the collection tank.

Operation of the collection tank distribution pumping will be automatic and controlled through a central control system. The control system will manage all return flows to plumes, or (if used) irrigation or golf course watering.

4.5.1.7 Piping and Well Header

All water distribution piping will be PVC or polyethylene construction. Because of the low levels of contaminants dissolved in the water, PVC and polyethylene are not expected to be adversely affected during the life of this project. All piping containing contaminated groundwater will be double-wall construction with interstitial leak detection units installed between the inner and outer pipes. Return piping containing treated water will be single-wall construction and will not have leak detection installed along the piping since any contaminants still in the water will be at extremely low levels.

The manifolds for the well fences will use a series of 10-foot-long sections of smaller diameter pipe to connect the wells to the manifolds. Each connecting pipe section will have a manually operated flow control valve, a totalizing flow meter/indicator, and directional check valve. Each well completion will also have a pressure gauge, and sample port.

All piping runs less than 500 feet long will be sized for pipe velocities no greater than 6 feet per second (ft/sec). Pipe runs longer than 500 feet will be sized for pipe velocities no greater than 4 ft/sec to limit friction losses and head requirements for the pumps. All piping will be rated to withstand a minimum of 150 psi at the operating temperatures expected (up to 80° F). Pressure switches will be installed to prevent rupturing of a section of piping. All piping will be static pressure tested prior to start-up.

All piping will be solvent welded or thermally bonded depending on the type of piping system used. Threaded sections will be used only when needed to attach valves, gauges, etc. to the piping. The piping will have expansion joints or be laid in the trench in a serpentine manner depending upon the expansion/contraction control requirements.

Contaminated groundwater flows from the various plumes will be combined whenever possible to reduce the cost of additional trenching and piping. Return flows will be kept in separate lines to allow flow controls to be used more effectively to maintain the injection rates to the groundwater at or below the extraction rates. It will also maintain continuous operations of the CTU and allow other plume well fences to remain on-line should a flow problem develop at only one plume.

4.5.2 Central Treatment Unit Control System

4.5.2.1 General Description

The containment system will be composed of 458 extraction and injection wells, 1,500 to 2,000 sensors, water treatment facility and a variety of other peripheral devices for maintaining continual operation of the system. In order to keep the system operational and synchronized, a closed-loop process control computer system is required. The system will be composed of sensors, low-level controllers, communications links, a supervisory computer and real-time software. The supervisory computer system will receive data from sensors via low-level controllers and control the process by adjusting flow rates and other variables. By monitoring and controlling the containment process, system operation can be optimized and serious problems

averted. The following sections describe the conceptual designs for the data acquisition and control, computer hardware and software.

4.5.2.2 Data Acquisition and Control

The first phase in developing a data acquisition and control (DAC) computer system requires the definition of the operational modes of the containment system. The containment system described in previous sections basically requires the operation of extraction wells, CTU and injections wells. The water treatment process will be continual except for periods of equipment maintenance. The normal operational modes include:

- System Off: system not operational.
- System Phasing Up: system ramping up, by pumping site.
- Normal Operation: all system components operational.
- Partial Operation: some pumping sites non-functional.
- System Phase Down: system shutting down.

The abnormal operational modes are due to non-functional components, erratic operations, and various combinations of the normal operational states. Analysis of the normal and abnormal operating modes, reveals the input and output variables that must be monitored and controlled in order to control the system. The conceptual description of the data flow and control is depicted in Figure 4.19.

The process input variables include:

- Fixed Variables: tank size, pipe size, other.
- Controllable Variables: flow rates, pressure, temperature, equipment status, other.
- Uncontrollable Variables: initial water pH, other.

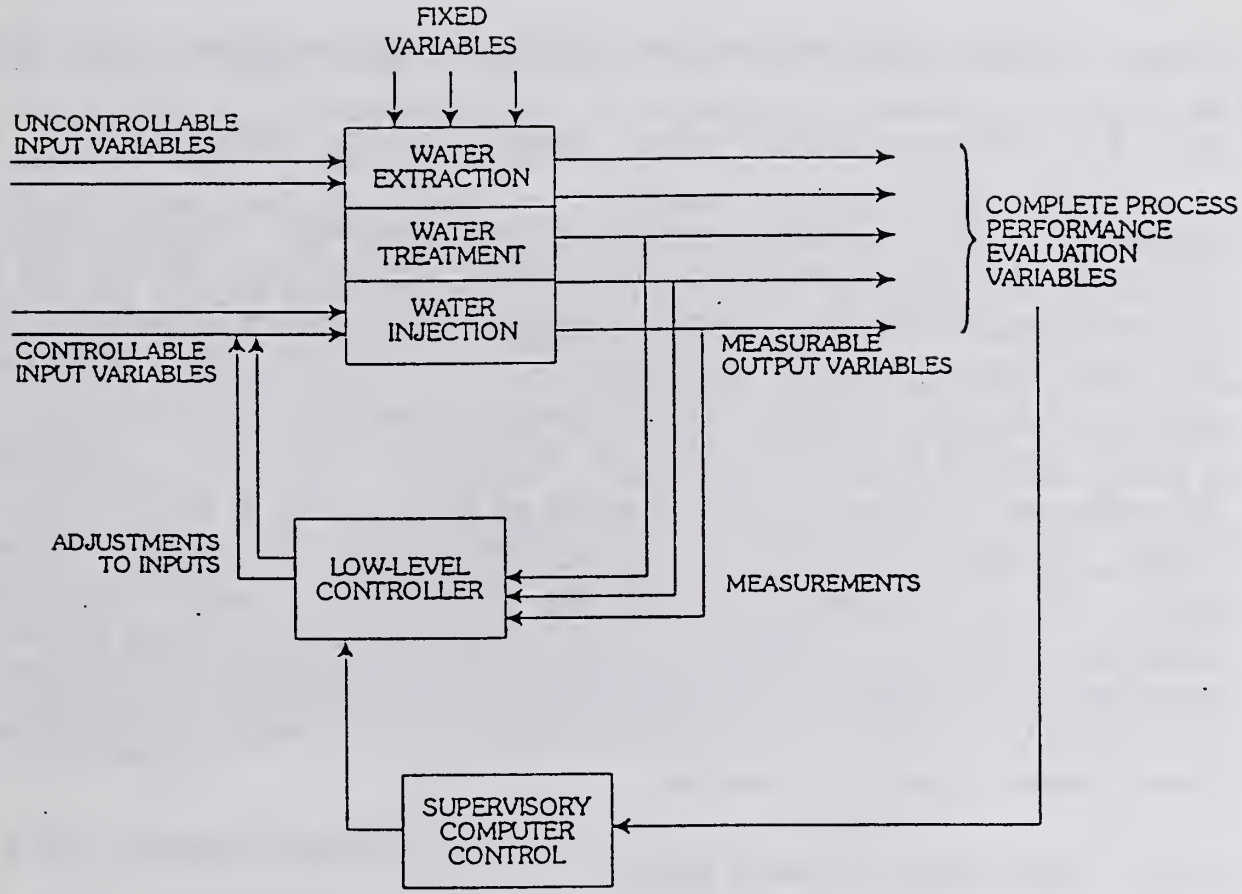

FIGURE 4.19

R\OTTS\P-TREAT

PUMP AND TREAT
PROCESS VARIABLES

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The input variables determine how the pump and treat system will operate. Initially, between 700 to 1,000 input variables will be defined for normal operation of the system. During operation of the system, only the controllable input variables will be varied, resulting in changes to the system operation.

The output variables are measurements of system operation and indicate the status of the system. Output variables include:

- Measurable Output Variables: flow rates, pressure, temperature, voltages, etc.
- Performance Output Variables: cost/gallon, cost/time, cost/well, etc.

Approximately 1,800 to 2,000 output variables will initially be captured. The output variables are captured by sensors and transmitted to the supervisory computer system, where the data is compared to set points and other information. Appropriate adjustments are determined and the new process control settings are transmitted back to the containment system resulting in adjustments to the process. Initially, some data is used to compute performance information that is used to determine the cost of operation and the efficiency of the system. Performance information can also be used to determine process set points, resulting in additional process control. All output variables and intermediate variables are stored on the supervisory computer system. After all the process variables have been identified, the relationships between and among the variables can be determined. These relationships must be identified for every operational state of the system. Timing and synchronization constraints should also be included. Having described the process variables, the conceptual design for the containment system process control computer system will be described.

4.5.2.3 Process Control Computer System

The containment process control computer system is a combination of hardware and software designed to conduct real-time process control of the entire system. Some of the basic requirements of the computer control system include:

- Real-time control of the entire pump and treat system.
- Simultaneous monitoring and control of up to 2,500 variables.
- High reliability, continual operation for up to 20 years.

- Redundant configuration.
- Modular.

To accomplish these objectives, a specific combination of hardware and software is required.

4.5.2.4 Computer Hardware

The computer control system is composed of low- and mid-level real-time computers interconnected with communication links for exchanging the monitor and control data. Figure 4.20 depicts the hardware configuration. The central or mid-level component of the control computer system is composed of two redundant real-time computers that operate in a fault tolerant mode. The ensures that one computer will always be available. The computers share disk and tape storage, system consoles and displays. These computers operate in a supervisory capacity by coordinating tasks among the low-level controllers with pre-defined set points and other process variables. The low-level controllers are programmable logic controllers capable of receiving analog or digital inputs from process transducers. The low-level controllers are physically and logically located close to the equipment to be controlled and conduct the real-time control of the well pumps. Other low-level controllers are used for capturing other process variables such as water tank conditions. The data from the low-level controllers is transmitted to the supervisory computer via redundant communications links. An appropriate bus interface is used at the supervisory computer to accept data from the low-level controllers. The supervisory computer includes telephone dial-in ports and modems to allow remote access to the system.

4.5.2.5 Computer Software

The mid-level supervisory computer system will be composed of an operating system and real-time process control software. This computer will use an operating system designed for real-time applications which includes the following features:

- Multi-tasking, multi-user operation.
- Process scheduling.
- Priority driven with many priority levels.

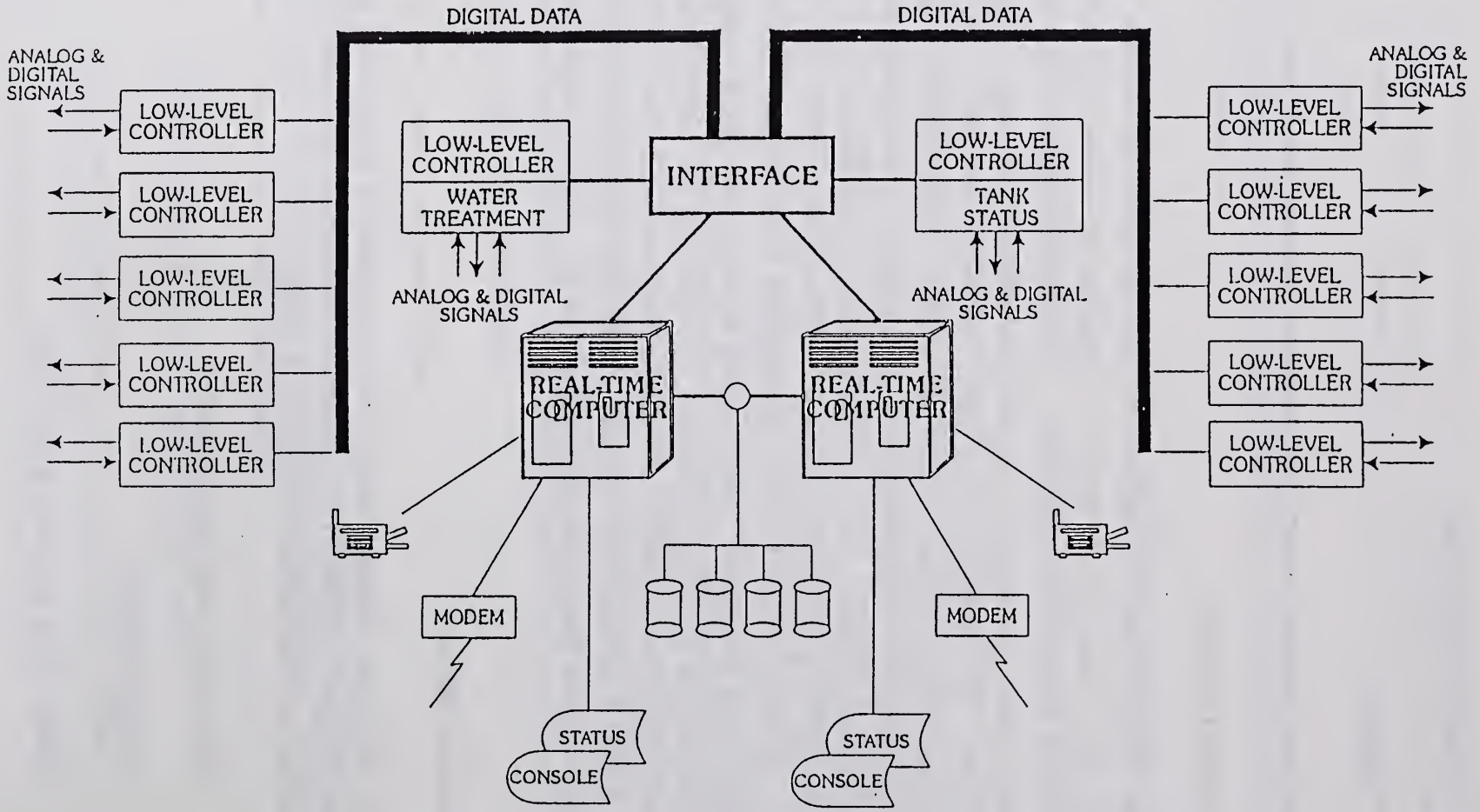

FIGURE 4.20

R\OTIS\REALTIME

REGIONAL SUPPLY vs DEMAND IN THE YEAR 2020

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- Interrupt driven operation.
- Time-sharing operation.
- Process spawning from parent processes.
- Process and network mailboxes.
- Low-level hardware access and software drivers.
- Many privilege levels.
- Full featured file system with security controls.
- Process synchronization with system event flags.
- Interprocess communications.
- Dynamic memory access.
- Compilers for high-level languages.
- Many data registers.

The operating system will manage the hardware and software resources of the supervisory computer. In addition, the operating system will service the real-time application software that will control the pump and treat process by capturing all required data and servicing software processes that model the containment processes to be controlled.

The real-time application software for the supervisory computer will manage and control the containment process. This software will receive all data transmitted from the low-level controllers, conduct analysis of the data and determine what process adjustments may be needed. In all cases, the incoming data will be stored in a central database accessible to several processes simultaneously. This software will operate continuously, similar to an operating system and will respond to interrupts or regular polling. This software will supervise the entire process by examining the status of all input variables and determining what adjustments are needed to any controllable component of the process. Once a change has been identified, the software will

transmit the appropriate corrective data to a low-level controller that will then conduct the low-level control of a component, such as well pump. Features of the real-time software include:

- Written in a language that allows low-level access to data and hardware.
- Procedural language.
- Language that allows inclusion of hardware system calls.
- Language can utilize system event flags.
- Software can be interrupt driven.
- Process spawning from parent processes.
- Access to process and network mailboxes.
- Parameter passing between subroutines or procedures.
- Dynamic memory access.

The conceptual plan for the real-time supervisory process control software is depicted in Figure 4.21.

In Figure 4.21, the data items are represented as pools, these are:

- Input data: incoming sensor data.
- Command data: commands such as start, spawn, wait, etc.
- Containment process data: pump and treat sensor data.
- User data: keyboard user input.
- Common data: data items shared by several software processes.

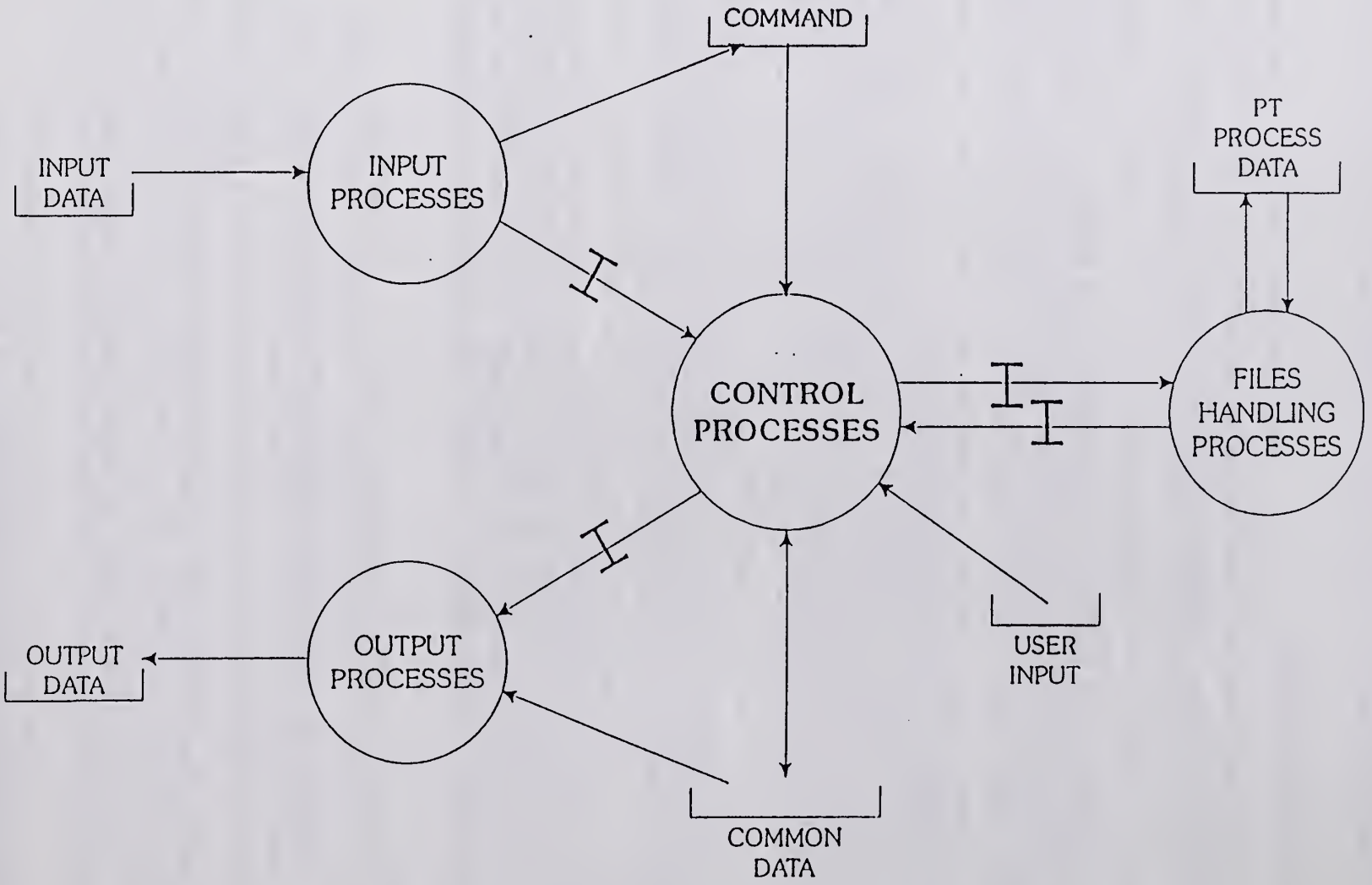

FIGURE 4.21

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REAL-TIME SUPERVISORY SOFTWARE-CONCEPTUAL DESIGN

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- Output data: outgoing data to control some aspect of the containment system. The real-time software processes are depicted as circles and include:

- Input processes: software routines that handle incoming sensor data.

- Control processes: software routines that supervise and control the containment processes.

- File handling processes: software that handles the data file activities.

- Output processes: software that handles the outgoing data to containment sensors.

The communication and synchronization channels are depicted by the I-beam symbols and represent the points where data is communicated between process groups, and where timing synchronization must occur. The diagram describes the high-level relationship among the main components of the real-time supervisory software. Each component in the Figure is composed of hundreds of details that would be identified in the detailed software design. In addition, all relationships among the components would be completely identified in the detailed design. The objective of the detailed software design would be to design real-time software that models the containment processes completely and correctly.

In addition to software operating on the supervisory control computer, operating system software and real-time software would be needed for every low-level controller. Low-level controllers normally include operating system software that provides all the necessary functionality for controlling low-level tasks. These controllers also include a high-level applications computer language that is used for customizing the controller's actions. Software routines would be developed and replicated for the low-level controllers using vendor supplied utilities and instructions. Since the controllers would perform a simpler set of independent tasks, this software is not as complicated as the real-time software to be used with the supervisory control computer.

The use of software at the low and mid-levels of the containment computer control system will integrate all the computer resources with the PT processes, thus allowing the entire system to be controlled with minimal human intervention.

4.6 COST ESTIMATE AND METHODOLOGY

On 1 September 1992, Mr. Gary D. Vest, then the Deputy Assistant Secretary of the Air Force (Environment, Safety and Occupational Health), issued a letter to all remedial project managers in the U. S. Air Force directing the use of a standardized approach to environmental project costing. For an 18-month period, Air Force environmental managers had developed a parametric cost engineering tool called RACER to assist in the costing of environmental projects. Using models of cleanup systems to cost specific remediation projects, RACER includes unit prices from the U. S. Army Corps of Engineers Unit Prices Book. RACER consists of two subsystems: Environmental Estimating (ENVEST) and Remedial Action Assessment System (RAAS).

With the fielding of RACER, the U. S. Air Force adopted the system as the required means to cost environmental projects. Beginning with all FY94 and outyear programs, RACER was required to be used by environmental managers and, if not used, the reason RACER could not be used was required to accompany all cost estimates.

OpTech used RACER to cost all elements of the Conceptual Model. Because it is modularized, specific RACER modules were used to cost the sub-elements of the Conceptual Model. In some cases, RACER modules required modification to apply to specific technological approaches; a standard U. S. Air Force costing practice. In all cases when modification was required, specific cost estimating information from environmental equipment manufactures, from records of similar projects, and from standard industrial sources were used to modify RACER modules. The result is the best possible blend of standardized governmental information from RACER with updated industrial costing information from technological sources.

The total cost of the central treatment unit approach within the Conceptual Model is approximately $100 million. Costs to contain and remediate the plumes through individual treatment units will add approximately 20 to 30 percent. Table 4.3 shows the projected construction and design costs associated with the proposed plume containment system for the seven plumes included in this scheme. Table 4.4 shows the first year operating and maintenance (O&M) costs.

4.7 LIFE CYCLE COSTS

OpTech used cost information from RACER to determine the first year O&M costs and then made adjustments based on expected life cycles of different technologies employed. Costs for

Table 4.3
Conceptual Model Cost Estimate

Module	Cost*
SD-5	$ 8,579,848.00
Eastern Briarwood	3,846,970.00
FS-12	16,838,516.00
Ashumet	23,587,528.00
FS-12	9,817,960.00
LF-1	14,275,704.00
Western Aquifarm	1,765,232.00
Central Treatment Unit	23,559,629.00
Total	**$102,271,387.00**

*Cost estimates include 1st year O&M.

Table 4.4
1st Year Conceptual Model O&M Cost Estimate

Yr O&M	Module	Costs
1st	SD-5	$ 205,360.00
	Eastern Briarwood	136,998.00
	CS-10	593,056.00
	Ashumet	424,180.00
	FS-12	165,080.00
	LF-1	430,816.00
	Western Aquafarm	143,026.00
	Central Treatment Unit	2,491,822.00
	Total 1st Yr O&M Costs	**$4,590,338.00**

Yr – Year.
O&M – Operating and Maintenance.

the 2nd through 20th years were adjusted using a 4.9 percent escalation factor. Life cycle costs are dependent on the technologies employed. Therefore, should the final design differ in technologies, used life cycle costs will have to be adjusted accordingly. A breakdown of life cycle costs show that 42.3 percent of costs are attributed to regulatory driven sampling requirements, 15.8 percent are attributed to energy requirements of the system, and 27.2 percent

are attributed to treatment material costs (carbon, chemicals, etc). Life cycle costs can be reduced if regulators agree to reduced sampling requirements once the efficiency of the system has been established. Energy and material requirements will be adjusted according to the final design. Life cycle costs for 20 years are contained in Table 4.5.

Table 4.5
1st Through 20th Year Conceptual Model O&M Cost Estimate

Yr O&M	Cost	
1st	Total 1st Yr O&M Costs	$ 4,590,338.00
2nd	Total 2nd Yr O&M Costs	4,815,265.00
3rd	Total 3rd Yr O&M Costs	5,051,212.00
4th	Total 4th Yr O&M Costs	5,298,722.00
5th	Total 5th Yr O&M Costs	5,558,359.00
6th	Total 6th Yr O&M Costs	5,830,719.00
7th	Total 7th Yr O&M Costs	6,116,424.00
8th	Total 8th Yr O&M Costs	6,416,129.00
9th	Total 9th Yr O&M Costs	6,730,519.00
10th	Total 10th Yr O&M Costs	7,383,082.00
11th	Total 11th Yr O&M Costs	7,406,270.00
12th	Total 12th Yr O&M Costs	7,769,177.00
13th	Total 13th Yr O&M Costs	8,149,867.00
14th	Total 14th Yr O&M Costs	8,549,210.00
15th	Total 15th Yr O&M Costs	8,968,121.00
16th	Total 16th Yr O&M Costs	9,407,559.00
17th	Total 17th Yr O&M Costs	9,868,529.00
18th	Total 18th Yr O&M Costs	10,352,087.00
19th	Total 19th Yr O&M Costs	10,859,339.00
20th	Total 20th Yr O&M Costs	11,391,446.00
	Total O&M Costs (20 yrs)	$150,512,374.00

Yr/Yrs – Year/Years.
O&M – Operating and Maintenance.

SECTION 5.0 RELATIONSHIP TO PLUME RESPONSE PLAN AS AN INTERIM ACTION TO CERCLA

The Superfund process, as mandated under CERCLA, defines the stages of the cleanup effort from site discovery and investigation through the implementation of final remedial actions. The 77 sites identified at the MMR are at various stages in the CERCLA process. The Plume Response Plan addresses accelerated interim actions at the nine major groundwater plumes which have been well defined as of December 1993. It must be emphasized that the site discovery process is ongoing and that the investigations and remedial actions at the identified potential source areas at MMR will continue. For example, remedial actions are underway at the Main Base Landfill, three areas of soil contamination, the FS-12 fuel spill source area, and over 100 drainage structures. Remedial Investigation/Feasibility Studies are being finalized for the Priority I Sites and Remedial Investigations and Site Investigations are in process for the Priority III Sites. Evaluation of potential problems related to the impact area and the inactive fuel pipeline is being conducted. These efforts will continue as mandated by CERCLA in parallel with the Plume Response Plan Interim Actions for the plumes.

Should additional plumes requiring containment be identified in the course of the investigations, the Plume Response Plan can serve as the basis for action. The proposed Central Treatment Unit system will be designed with the flexibility to address additional plumes if necessary.

The simultaneous containment of the major plumes as proposed in the Plume Response Plan would proceed as an Interim Action, as defined under CERCLA. The steps of the CERCLA processes following site discovery, preliminary assessment, and site investigation are discussed below.

(1) Remedial Investigation (RI) – This report identifies the nature and extent of contamination, and performs a Risk Assessment to determine the risks posed by the contamination which has been identified.

(2) Feasibility Study (FS) – This study, based on the results of the RI, evaluates the feasible technologies and alternatives and performs a detailed analysis of these alternatives.

(3) Proposed Plan – This plan collectively evaluates the alternatives examined in the FS and identifies a preferred alternative which is determined to be protective of human health and the environment. A public comment period, a public

informational meeting, and an informal public hearing are held to discuss the RI/FS findings, the alternatives evaluated and the proposed alternative.

(4) Record of Decision (ROD) – The ROD documents the remedial action for an operable unit or site, and serves the following purposes:

(1) Certifies the remedy was carried out in accordance with CERCLA.

(2) Describes the performance criteria parameters of the remedy and the remediation goals.

(3) Provides the public with a consolidated source of information about the site and the selected remedy, including the rationale behind the selection.

(5) Remedial Design (RD) – This next phase includes the detailed engineering design of the remedy selected in the ROD.

(6) Remedial Action (RA) – Upon completion of the RD, the actual construction of the remedy commences and cleanup occurs. The remedial action will continue until all phases of the remedial activity has been completed and no further remedial action is warranted.

The completion of the above steps can be time-consuming. In some instances, the time until remedial action construction begins may be approximately 3-1/2 to 7 years from initiation of the Remedial Investigation.

However, during the scoping process or at other points during the RI/FS process, the lead agency may determine that it is appropriate to implement an interim action at a site. Interim actions, which may be either removal or remedial actions, can be taken to respond to an immediate site threat or to take advantage of an opportunity to significantly reduce risk quickly. Interim actions are limited in scope and are followed by other remedial actions that complete the steps to provide definitive protection of human health and the environment for the long-term. Examples of interim actions include:

(1) Constructing a fence a restrict access to the site.

(2) Pumping or containing a groundwater aquifer to restrict migration of a contaminant plume.

(3) Providing an alternative source of drinking water.

One interim action has already been implemented at MMR. A groundwater plume originating from the CS-4 source area migrated approximately 11,000 feet downgradient and across the MMR property. If no action were taken, this plume could threaten private residential wells located in the Coonamesett Pond area and a public supply well also in the vicinity. The FS identified various treatment alternatives, one of which included both containment of the CS-4 plume as well as installation of extraction wells throughout the plume, thus reducing the amount of time until the remediation would be complete. However, this alternative could not be selected due to the fact that another plume, originating from the CS-10 source area, had not been fully defined, and the CS-10 plume goes under the CS-4 plume. Therefore, until the CS-10 plume was fully characterized, it was unclear what impact installing extraction wells throughout the CS-4 plume could have on the deeper CS-10 plume.

As a result, an interim action for the CS-4 plume was initiated, which consisted of installing 13 extraction wells at the leading edge of the CS-4 plume, pumping the groundwater and treating it through activated carbon prior to its discharge back to the ground.

If an interim action is implemented, the remedy which is selected should be as consistent with the final remedy as possible. This is necessary in order that the final remedy will not result in a completely different remedy selection and the expenditure of additional significant funds.

Innovative technologies should also be considered in the use of interim actions; however, it may not always be feasible to conduct sufficient treatability testing to address all of the uncertainties associated with an innovative technology. If an innovative technology is selected, a contingency remedy can also be selected if subsequent testing prior to its installation indicates that the innovative technology will not fulfill its performance expectations.

The use of an interim action requires that a final remedial action be selected at a point in the future, normally within five years of the interim action. The final action must investigate all the various alternatives which were developed in the FS. However, upon evaluation of the alternatives, it is possible that the final remedial action may be the same as the interim action, which has already been implemented, if the remediation goals can be achieved.

In evaluating the simultaneous containment of the MMR groundwater plumes, the PAT compared the time frames for proceeding under the current schedule contained in the FFA with the Plume Response Plan. This plan can serve as the equivalent of a Feasibility Study, and upon approval, can immediately proceed to the preparation of a Proposed Plan and an interim Record of Decision. It is anticipated that the development of these documents would be placed on a fast track so that a Proposed Plan could be issued in February 1995 and a Record of Decision option could be signed in June 1995. Table 5.1 outlines the dates for the submittal of the required documents for the various groundwater plumes under the FFA compared to the PAT's proposal for simultaneous containment.

Table 5.1
Federal Facility Agreement Schedule

Area of Contamination	Feasibility Study	Proposed Plan	Record of Decision
SD-5	6/95	1/96	10/96
CS-10	10/94	5/95	2/96
FS-12 (Sandwich)	10/94	5/95	2/96
Ashumet Valley	11/95	6/96	3/97
LF-1	3/95	10/95	7/96
Plume Response Plan (All Plumes)	6/94	2/95	6/95

It is evident that the implementation of an interim containment action which simultaneously addresses all the groundwater plumes at the MMR will significantly reduce the time frames involved in design, construction, and implementation phases. An important advantage of combining the containment of the groundwater plumes into a single interim action occurs during the design and construction process. Design activities could be consolidated and savings could be realized through the development of one set of plans and specifications, as opposed to numerous design documents. In addition, the construction cost and time will probably be reduced by awarding one large contract as opposed to separate smaller contracts. Additional documents such as remedial action plans and health and safety plans for the implementation of the remedy can also be consolidated, saving money and time in regulatory review. Combining regulatory activities at every step of design, construction and implementation offers significant savings in time, effort, and funding.

One of the major advantages of addressing the groundwater plumes collectively rather than individually occurs in the public participation process. During the 30-day period that a Proposed

Plan is made available for formal public review and comment, a public meeting and hearing is held to consider the recommended alternative as well as alternatives that were evaluated and not selected. A Responsiveness Summary, which addresses and responds to the public comments made during the comment period, must be prepared and attached to each Record of Decision. With five actions, this can be a tedious and time-consuming activity.

Combining the containment of the plumes into a single interim action consolidates public comment periods for Proposed Plans, Records of Decision and Responsiveness Summaries into a single activity, rather than five separate activities as outlined in the above table. This greatly reduces the amount of paperwork that must be generated. Therefore, the implementation of the recommendations contained in this plan as an interim action which would be addressed in a single Record of Decision would derive significant benefits as opposed to the existing schedule contained in the Federal Facility Agreement.

The implementation of the recommendations contained in this plan as an interim action, to be addressed in a single Record of Decision, offers significant benefits over the existing schedule contained in the FFA.

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SECTION 6.0 PLUME RESPONSE PLAN PUBLIC ACCEPTABILITY PLAN

6.1 INTRODUCTION

Central to the success of the Plume Response Plan is public acceptance and support of all aspects of the plan. While public opinion on the Upper Cape strongly favors immediate, effective and cost efficient action on the plumes, the details of those actions, including property access, construction, and traffic impacts, must be carefully considered together with the input of the people directly affected.

The Plume Response Plan therefore includes an intensive public outreach component that will engage concerned citizens well in advance of actual implementation of any plume remediation activity. Since the PAT developing the Plume Response Plan includes members of citizen advocacy groups, and most PAT members have extensive public involvement experience with MMR issues, the PAT anticipates that the majority of potential public concerns have been identified. Efforts to minimize or eliminate impacts and address all major concerns have been incorporated into the Plume Response Plan.

The Plume Management PAT intends to incorporate all elements of public involvement specified by the National Contingency Plan, (see the MMR Joint Public Relations and Community Involvement Plan). The Plume Response Plan meets or exceeds all requirements for community involvement under the NCP. The PAT's Plume Response Plan is innovative, fast-track, and forward-looking, and a public acceptability plan that maximizes participation of affected citizens has been developed.

The conceptual Plume Response Plan serves as the basis for an initial public presentation and public concerns scoping session. This general meeting will be held by the PAT, followed by a series of meetings in those towns where containment systems are proposed for installation. Public input on the conceptual design and proposed plan for the containment and treatment of the MMR plumes will be sought. Public participation in formulating the proposed plan will specifically be obtained.

Public concerns related to plume containment, to be addressed in the public acceptability plan meetings and incorporated into the design of the containment systems, include:

- Safety of children living near construction sites;

- Public health and safety of residents living near treatment systems;
- Access to private property for placement of wells and treatment systems;
- Noise generated by extraction wells and treatment systems;
- Traffic generated during construction of treatment systems;
- The potential for drawdown of the Upper Cape water table, thereby affecting private wells, wetlands, cranberry bogs and other surface water bodies;
- Impact of construction on natural areas, including wetlands and wildlife habitats;
- Anticipated length of time of construction activity;
- Anticipated length of time for treatment system operations; and
- Any related issues.

6.2 PUBLIC ACCEPTABILITY PLAN COMPONENTS

The specific elements of the public acceptability plan are described below. A schedule for implementation is included as Table 6.1.

(1) Two public meetings will be organized by the PAT once a conceptual Plume Response Plan has been endorsed by the Senior Management Board and presented to the USAF and Army Secretariats.

Meeting #1: Town and State Governance

Selectmen in each of the four towns surrounding the Base, and State Legislators, will be invited to attend an **evening meeting of the PAT** where they will be briefed on the proposed Plume Response Plan and given the opportunity to discuss any concerns they may have. Selectmen will be asked to bring town engineers, health agents, conservation administrators, and other appropriate personnel to provide input on access, location of wells, piping and associated equipment, and other physical considerations for installation of containment and treatment systems. Any important considerations identified in this meeting will be incorporated into the

Table 6.1
Proposed Schedule for Public Acceptability Plan Implementation

	May 1994	June 1994	July 1994	August 1994	September 1994	October 1994	November 1994
Senior Management Board Meeting	X						
Town & State Governance Meeting			X				
Town Citizenry Meeting			X				
Legislative Summit			X				
CS-4 Site Visit			X				
Plume Fact Sheet Preparation		X					
Neighborhood Associations Meetings			X				
Interested Organizations Meeting			X				

Plume Response Plan by the PAT. While the PAT meeting will be directed at town officials, it will be open to the public and media, with a time period at the end of the meeting for comments from anyone in attendance.

Meeting #2: Town Citizenry

A General Public Meeting to present the Plume Response Plan and invite discussion will be held in the evening subsequent to the town governance meeting. Public notice will be by way of a general resident mailing, notice through other citizens groups, the MMR mailing list, Cape Cod Commission Reporter, and paid advertisements in the Cape Cod Times, Falmouth and Mashpee Enterprise and Cape Cod Publishing Co. weeklies. Fact sheets and a schedule of community and neighborhood association group meetings will be provided at the general public meeting. A display board depicting photographs of installation and operation of the existing containment system at CS-4 will also be provided to familiarize the audience with the nature of the proposed work. Representatives from the IRP Office, MDEP, USEPA, and OpTech, etc. will be on hand to answer specific questions regarding health concerns, system design, and monitoring plans.

(1) **A Legislative Summit Meeting and Strategy Session** will be held to discuss the PRP with the Massachusetts Federal delegation and governor's representatives. The meeting will be held off-base in the evening and be open to the public.

(2) **Public visits to the CS-4 treatment system will be arranged** to familiarize members of the public with the containment system components in light of the proposed Base-wide plume containment proposal.

(3) **Plume Response Plan Fact Sheets** will be developed and distributed to public mailing lists and the media prior to public meetings. These sheets will describe the basic characteristics of each plume, and specifics of the Plume Response Plan, including:

- Objectives of the plan;
- Potential well locations;
- Treatment system design;
- Estimated duration of system operation;
- Emergency contingency plans;
- Construction duration and impacts;
- Operation and maintenance;
- Air and water quality monitoring plans; and
- Cost ranges.

(4) Individual **Neighborhood Associations** such as the Briarwood Association, the Ashumet Valley Property Owners, Inc., and the LF-1 Committee will be contacted to arrange a meeting of their group with the PAT to discuss the Plume Response Plan and provide reaction to it. Fact sheets and photographs will again be provided.

(5) Meetings for **Interested Organizations,** including the Cape Cod Chamber of Commerce, local labor unions, Veterans Groups, the Cape Cod Breast Cancer Coalition, Sierra Club, Massachusetts Audubon Society, Trout Unlimited, Wampanoag Tribal Council, the Upper Cape Council of Churches, and the Cape Cod Center for the Environment and a Sustainable Economy will be held by the Plume Management PAT so as to create broader understanding and support of the proposed Plume Response Plan.

(6) The MMR IRP Public affairs Office will include **Detailed Updates** of the progress of the Plume Response Plan in their quarterly *Environmental Update Fact Sheet*. A PAT member will review and edit stories prior to publication.

(7) A **traveling display** of the containment project will be prepared and placed in appropriate locations. The display will contain photographs, plume maps, details on the containment system design and how it works, and sampling/monitoring data.

(8) Upon installation and throughout operation of containment systems, the air/water **monitoring results** will be made readily available to the public. Fact sheets will be issued quarterly, summarizing test results. Monthly reports will be provided to local papers and distributed to lists of interested people and to local Boards of Health.

(9) The PAT and Otis IRP office will hold **biannual public meetings** to present the results of containment system monitoring and ask for suggestions for plan improvement.

6.3 MEETING MECHANICS

(1) **All public meetings outlined in this plan will be held in the evening at locations convenient to the target audiences such as public schools and libraries.** Comments and concerns received at the general public meeting, neighborhood association and other meetings at which the Plume Response Plan is discussed, will be addressed at each meeting and incorporated into the ongoing implementation scheme. Minutes will be taken of each meeting and those minutes provided to the local libraries. Any person with comments and concerns that

require a response after a meeting has been concluded will receive a written response to the concern.

(2) A motion was accepted during the 15 June 1994 Senior Management Board (SMB) meeting that the SMB recognizes that the Plume Management PAT is critical to the development and implementation of the PRP until the proposed plan is endorsed.

6.4 MEETING CONTENT

Each initial meeting will cover the following:

(1) The known, anticipated, and potential public health and environmental impacts of the contamination plumes at MMR.

(2) History of PAT establishment – how and why this approach is being undertaken, who is involved, when and what accomplishments are expected.

(3) How the Plume Response Plan fits into the CERCLA process, rationale from accelerated approach, presenting figures on loss of resources, effect on public health, effect on property values, and psychological impacts, and how public involvement will be achieved.

(4) The nature and elements of the Plume Response Plan, describing each plume and the proposed containment approach for it, and the overall effect of the program in the context of an interim action. Details to be covered include:

- Specifics of the containments process: design and construction details, emergency contingency plans, backups, monitoring plans, mechanism of effectiveness, amount of water to be treated per day and per year;

- Hydrogeologic considerations in the design of each plume's system, and the design limitations imposed by the proximity of some plumes to Johns and Ashumet Ponds; and

- The proposed discharge location for treated water.

(5) Public concerns and nuisance factors that can be expected by residents in areas of containment systems, specifically those listed in Section 6.1 above, and how these will be mitigated.

(6) Evaluations criteria and schedule for Plume Response Plan performance.

(7) Future considerations:

- Overall effectiveness.
- Predicted vs actual hydrogeologic impacts.
- Acceptability of hydrogeologic impacts.
- Duration of operation.
- Transition to cleanup.
- Time frames for revisitation and adjustment.

(8) Meeting assessment. The audience will be asked to provide feedback on the format and usefulness of the meeting and suggestions on style and content for the next meeting.

Under the provisions of the Joint Public Involvement/Community Relations Plan, there are certain requirements that need to be fulfilled for actions that are derived through the Plume Response Plan. The Plume Response Plan, including the Public Acceptability Plan, will be the foundation for a Proposed Plan under CERCLA. When the Proposed Plan is publicly released to the local libraries and the MMR reports mailing list, a series of public meetings will be scheduled to present the plan at a time and place convenient to area residents. A 30-day formal public comment period will begin the day after the public meeting. The comment period can be extended an additional 15 days upon receipt of a single written request. During the third week of the 30-day public comment period, in at least two locations, meetings will be held to solicit oral and written comments from the public. Written comments can be provided throughout the public comment period. All oral and written comments received at the public hearing and written comments received during the public comment period will be seriously considered by the NGB for incorporation into the Proposed Plan and will be responded to in the

form of a responsiveness summary document. The responsiveness summary will be part of the Interim Record of Decision document that will be issued at a later date.

SECTION 7.0 PROJECT MANAGEMENT PLAN

The Plume Response Plan (PRP) describes a very large and complex project. It will require extensive labor, material, and financial resources for many years into the future. However, the most crucial point in the PRP development is during the planning for implementation which will set the stage for all future successes. A project management plan should be developed to efficiently manage and coordinate the considerable resources that will be expended on this project.

To successfully move from the concept stage of the PRP to implementation will require the consulting services of a firm with a solid track record in the management of large infrastructure type projects. The MMR project will involve hundreds of tasks in the planning stage alone that cover a spectrum of functional areas, from public acceptability and private access issues to regulatory review, detailed scheduling and contractor and subcontractor coordination. All of these functional areas must be planned and managed with adequate oversight to insure they all come together with the appropriate level of urgency that this project demands and with as little disruption to the community as possible.

Upon approval of the PRP by the Army and Air Force Secretariats, a statement of work that has been developed by the MMR IRP office will be implemented to secure the services of a project management firm that will immediately enable us to conduct task analysis and master scheduling. This work will be done concurrently with the scoping of design services for the construction phase of the PRP. The significant size and scope of the design services contract prescribe the need for immediate project management services.

The management plan contract will require the contractor to provide detailed planning and scheduling consistent with the requirements of the PRP and the National Guard Bureau. The management plan will incorporate the following elements:

- System Design;
- Public Acceptability/Community Involvement;
- CERCLA Integration/Federal Facility Agreement;
- Regulatory Review;

- Health and Safety;
- Public and Private Access;
- Construction/Oversight;
- Procurement; and
- Operational Requirements.

The contractor will be required to provide task analysis for each functional area. This will include scheduling time frames as well as developing a master schedule detailing "critical tasks" that could result in project delays if not performed in the proper sequence or within the allotted time frame. The master schedule will be a "living" document that will be regularly updated and revised as the needs of the project dictate. The management plan should incorporate flexibility as a parameter in order to deal with and respond accordingly to inevitable unforeseen circumstances.

The MMR plume containment project is likely to be one of the largest public works projects in Cape Cod history, next to the construction of the Cape Cod Canal and bridges. It will affect many aspects of Cape Cod life, from economics to recreation to quality of life, but most of all in the protection of public drinking water supplies and the ecological integrity of fresh and marine surface waters. Quality professional project management will insure that the PRP is implemented as expeditiously and safely as possible and with as little disruption as possible to those who live, work, and play here.

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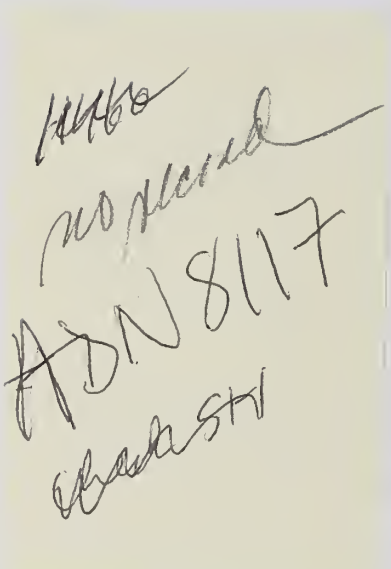

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